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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

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THE MIRIAMITES

By HUBERT LYMAN CLARK

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ALTHOUGH the name sounds Biblical, the Miriamites are not one of the lost tribes of Israel. There is nothing Hebraic about either their faces or their language. Yet there is some justification for calling them a lost tribe, for they dwell far removed from their racial stock on a few small islands in the Coral Sea. Living as they do under the protection of the Queensland government, yet seldom in touch with white men, they have retained a child-like simplicity and charm which makes them unusually interesting to those who are fortunate enough to visit the islands where they dwell. The shallow water of Torres Strait abounds in islands, many of which are, or have been, inhabited, but on only those lying most to the northeast have the Miriamites found a home.

These islands are known to their own people as Erub, Mer, Dauer and Weier. On English charts, however, Erub is called Darnley Island, while the other three are grouped together as the Murray Islands. Erub is the largest, having a shore line of perhaps eight miles, but Mer is the highest, the "top of the island" being 750 feet above the sea. The Murray Islands lie only four miles within the Great Barrier Reef and from the summit of Mer the long swell of the Pacific beaten into snow-white breakers upon it is easily seen. Dauer and Weier are little more than a mile south of Mer, but Erub lies twenty-five miles to the north. All through the region, reefs and shoals abound and upon some of these the ceaseless movement of the sea has built low islands, a few of which are more or less covered with vegetation, including, of course, the ubiquitous coconut palm. A few miles north of Erub lies one of the largest of these coconut-islands, Uga (Stephen's Island of the charts), noted for its fertile soil. Uga shares with Erub and Mer the honor of being the home of the Miriamites.

Centuries ago, long before Torres sailed through the strait which bears his name, Australia was the possession of nomadic tribes of a lowly black race, remnants of which are now the wards of their Anglo-

Landing on Erub.

Saxon conquerors. New Guinea was peopled by a primitive Melanesian stock, of relatively low intelligence. Northwestward in the East Indies was a higher, stronger, more pugnacious race. Slowly but steadily, pressure from the Malay archipelago initiated one of those migratory movements for which the region is renowned, and the simple people of northern and eastern New Guinea were forced to move. Many turned westward into that part of the island now under Dutch control, where they were isolated by the encroachments of the higher race which soon dominated eastern Papua. Others, following lines of least resistance, passed southward to the islands which abound in Torres Strait. The eastern Papuans, however, were not content with driving their less pugnacious brethren before them into the islands. They followed them there, conquered them, intermarried with them, and thus gave rise to the bright, intelligent natives of Badu, Moa and the other islands lying north of Cape York. But for some unknown reason, the few small islands at the northern end of the Great Barrier Reef, far to the eastward of Cape York, were never reached by the conquerors and there a fragment of the defeated race, the Miriamites of the present time, have found a sanctuary to this day.

Indefinitely long ago, volcanic outbursts, accompanied by great changes of shore-line along the Queensland coast, disturbed the region now covered by the Gulf of Papua, and New Guinea was finally separated from the Australian mainland. Volcanic peaks and cones, scat-

tered here and there, still remain as traces of the old land-bridge. Of these, because of their present isolation and beautiful scenery, the most interesting are the four above mentioned and which still show clearly their volcanic origin. The soil is very fertile and, except on almost vertical slopes, is thickly clothed with vegetation. The torrential downpour of the rainy season has greatly softened all rugged outlines and surrounded each island with a narrow strip of level land on which the coconuts flourish. The rains too give rise to streams which have cut deep and picturesque ravines and gorges on their way to the sea. But during the long rainless season, these stream-beds become quite dry and for a water-supply, the people have to depend on a few deeply sunken cisterns and on storage tanks.

The Miriamites are so similar to negroes in their general appearance, a close examination is necessary to show that they are not really of negroid stock at all. The very dark skin, broad nose and woolly hair are characters obviously like those of Africans, but the shape of the skull and the thinner lips are evident differences. Customs and language yield satisfactory proof that the ancestry was Melanesian and not even remotely traceable to Africa. The language is particularly interesting and is of great importance in attempting to follow the history of the islanders. The speech is known as Mer or Miriam and hence the people, though usually called Murray Islanders, should be designated as

THE CHURCH AND PARSONAGE AT ERUB.

GOING INTO SCHOOL, ERUB.

Merites or Miriamites. The former name, however, implies birth or residence on Mer and so, like "Murray Islanders," is objectionable, since half the Miriamites live on Erub and Uga. Nobody knows how large a company first found shelter on the islands, but, at the present day, there are between eight and nine hundred, all told. Of these about half reside on Mer, more than three hundred on Erub and the remainder on Uga. Dauer no longer boasts any permanent residents, but gardens are still maintained there by natives living on Mer. The improved social conditions on the larger island, accompanying the development of church and school, caused this short but complete migration. A similar movement is now in progress further north, where the people of Uga are passing over to the socially more attractive, but agriculturally less desirable, Erub. In this case, however, Uga is so fertile and lies so far from Erub, it is not likely to ever wholly lack inhabitants as Dauer does to-day. Vital statistics kept on Mer for the past twenty years show that the Miriamites are not dying out, but are rather more than holding their own. The abundance of children on both Erub and Mer is further confirmation of the fact.

Intellectually the Miriamites do not rank high. Their language is curiously complex in certain details, particularly in prefixes and suffixes to verbs to express slight differences of sense or of mood and tense. Yet in vocabulary there is a striking absence of many common words and even numerals above two were lacking in the original tongue, though now transferred more or less bodily from English. Thus in the

translation of the Gospels, used in the churches, two is *neis,* but three is *thri;* four is *neis a neis* or *foa;* five is *faif;* six, *sikes,* etc. Apparently for practical purposes, counting "one, two, few, many," answered all requirements. Although the schools are conducted in English, and have been for twenty-five years, few Miriamites speak the language readily enough to maintain conversation in it. Most of the dealings with foreigners are transacted in a curious "pidgin English" which knows neither case nor gender, but which is remarkably effective for conveying ideas.

About forty years ago, the London Missionary Society began work among the Torres Strait islanders and Erub and Mer were two of the first stations occupied. Schools were of course a very vital part of the work, so that for more than a generation the Miriamites have had an elementary English education. The children take to school work well, but sooner or later seem to reach an intellectual limit beyond which they can not progress. It is a notable fact that not one of the pupils has shown sufficient ability and inclination to become a teacher of his own people. At the present time, the Miriamites are all nominal Christians, and their island homes are no longer mission stations. There is a church on each island maintained by the London Missionary Society. On Erub, the pastor is an Ellice Islander, while on Mer a Samoan looks after the spiritual interests of the people. These men are intellectually far superior to their parishioners, but they live the same simple, easy-going life and hence do not seem so foreign as white men would.

A Group of School Children, Erub.

The Queensland government maintains a school on Erub and another on Mer. These schools are in session from forty to forty-five weeks each year and are taught by white men who are also the general representatives of the government. Mr. Williams, the teacher at Erub, is a Welshman who has been a lay-missionary in New Guinea, while Mr. Bruce, the teacher at Mer, is a Scotchman who has resided there twenty-three years, and so is now a father to the whole island. It is remarkable and most fortunate that it is possible to procure for these isolated schools men of such intellectual caliber and rugged Christian character. Situated as they are, their responsibilities are really very great, for the Miriamites are very child-like, easily led and easily misled. To protect them, the Queensland government has made their island homes reservations upon which no whites or other foreigners may take up their residence. Nor may they even remain on shore for so much as over night without official permission. The sale or giving of liquor to the people is, of course, prohibited, and there is little violation of this law. White men are rare visitors to these out-of-the-way islands, the principal foreigners being Japanese employed on pearl-fishing boats.

Thanks to the paternal care of Queensland, the Miriamites are rarely in want. Men, women and children look well-fed and healthy. They are cleanly in their habits, and skin diseases and other repulsive evidences of unsanitary living are conspicuous by their absence. The men are well-built and often fine appearing; a few are positively handsome, with bright, intelligent faces. The women, too, especially the younger ones, are attractive and often really good-looking. Both sexes work in the gardens and both join in the fishing, but the women seem to be more persistently industrious and are less given to playing games. Fifteen or twenty years ago one of the chief amusements of the men was making and spinning tops. These were of simple, but unusual, construction. A stone of volcanic origin, evidently consolidated ash, was split in two and the half was ground into as perfect a lens shape as possible, flat above and evenly convex below. A hole was bored through the center and in this was inserted a hard-wood stick. The flat upper surface of the top was usually adorned with one or more colored circles. These stone tops were from six to nine inches in diameter and weighed several pounds. When skilfully handled, a perfect one would spin for twenty-five minutes or more! The top-spinning craze became so absorbing that it was finally necessary to put certain restraints upon it. With characteristic childishness, the men turned to other amusements and the fad rapidly died out. At the present time there is no top-spinning on Mer, tops are no longer made and it is very difficult to procure a good specimen of the toy. Just now a kind of ball game, in which a small ball is batted about in the air by the hands, is very popular, a half-dozen or more men playing on each side. Sometimes the younger women join in this game and then the hilarity is considerably increased.

As in many a better-known community, one of the diversions of the men of Mer is politics. The island is divided into four districts, each of which is entitled to a member of the Council, which under the guidance of Mr. Bruce governs local affairs and looks after the maintenance of order. Elections are held in December, biennially. It is regrettable to find that even in such a small and simple community the difficulty of getting the office to seek the man rather than the ambitious man the office occurs, as in our own land, and unfit men are occasionally chosen. At the election in 1912, a man called "Benny" was elected one of the four councilors. About two months later, it was reported that there had been a disorderly disturbance in Benny's village and the councilor, instead of attempting, in accordance with the dignity of his office, to maintain order, had actually been mixed-up in the affair. He was arrested and tried. Being found guilty, he was reprimanded and released on his good behavior. But alas for human frailty, the very next day he became an active participant in another fight. This was too much for the orderly Miriamites. Benny was deposed from office and a special election was immediately held for the choice of his successor.

Fishing and gardening are the chief serious occupations of the men. Some of them find employment on pearling boats, where the use of a pump to supply air to the diver necessitates a large amount of cheap, unskilled labor. Both Erub and Mer own small schooners (called cutters), which are manned by residents of the owning island. These vessels serve not only as a means of communication with the outside world, but are also employed in gathering beche-de-mer, for which a ready market is always to be found at Thursday Island. During the rainy season great schools of fish visit the reef-flats of Erub and Mer. To capture them, the people have built stone walls extending out some distance from high-water mark and connected across the ends by similar walls parallel to the shore. At low water these fish-pounds are more or less completely drained, but at high tide they are filled and the outer walls, at least, are covered by several feet of water. (The rise of spring tides may exceed ten feet.) The fish come in with the rising tide, following it nearly to high-water mark. When it ebbs, they retire slowly, keeping near the bottom and thus they become prisoners within the pounds. This wholesale capture of fish is one of the most characteristic features of Miriamite life and is the most notable occupation of the rainy season. In the dry season, fish are captured in small numbers by spearing and now-a-days the hook and line method is not disdained. Marine turtles appear more or less regularly all the year round and from the Miriamite point of view are among the most useful animals of the sea. Both the eggs and the meat are highly regarded and the capture of a turtle or the finding of a freshly-laid batch of eggs is a cause for great rejoicing.

Domestic animals are in little vogue on either Erub or Mer. Now and then a dog, pitifully thin and dwarfed from long-enforced vegetarian diet, is a treasured possession of some family. A few cats are to be seen and as they no doubt capture mice and birds and make a comfortable living at it; they look far more healthy than the dogs. At various times cattle, goats and pigs have been tried on Mer, but all of these animals have so persistently sought the gardens for their foraging grounds that they proved to be intolerable nuisances and it was necessary to exterminate them. Chickens are kept in some numbers and both they and their eggs are greatly prized.

IN GALA DRESS.

The gardens on Mer, to which reference has already been made, cover a large part of the northern half of the island. The whole interior of Mer is raised two hundred feet or more and a large part of this plateau is very fertile. There are no dwellings there, all of the people living on the flat strip of land which borders the northern and western sides of the island. As the journey to the gardens is rather long and involves a very steep climb, it is customary to go up for the day, taking along some food and water for refreshment. Sometimes a considerable party go together and make a real picnic of the affair, the work on such occasions occupying a secondary place in the day's program. If food is plentiful, the party join in a "kaikai" or, in American college slang, an "eat." Should there be many present and provisions abundant, the occasion becomes an "aule kaikai" or great feast, literally a "big man eat."

The two staple crops of the islands upon which the Miriamites really depend and in the cultivation of which they constantly labor, are yams and bananas. There are several varieties of yams grown, the commonest being much like an American sweet potato but with very pale yellow flesh. The most remarkable yam is a large, white one, the vines of which are such climbers that poles are used to lead them up into trees, where they have abundant opportunity to spread. It is a common thing to find a tree, surrounded, at a distance of twelve to fifteen feet from the trunk, by a circle of ten or a dozen yam-hills from each of which a long, slender bamboo pole reaches into the branches. Yams are planted in the early part of the rainy season and are dug as occasion demands after the dry season is well under way. Bananas are cultivated in even greater variety than yams, no fewer than twenty-two kinds being grown on Mer. Some of these are really plantains and are used only after being cooked. Some are delicious little fruits only two to four inches long and an inch thick, with thin skins and firm, sweet flesh. Others are big, pulpy bananas, five to seven inches long and two to three inches in diameter. Owing to the abundance of very large yellow locusts, which would do great damage to the ripening fruit, it is customary on Mer, when the bananas are full-grown, to wrap the bunch in "trash" (*i. e.*, dried banana leaves), while it still hangs on the tree. There it is allowed to remain until wanted. The wrapping is done very neatly and the nicely tied-up bunches give an odd appearance to the gardens. Aside from yams and bananas, little is cultivated by the Miriamites. Papaws are grown in some numbers and the trees bear very well. Now and then a large pepper plant with bright red fruits is seen in the gardens. Coconuts grow in great profusion on all the lower parts of the island, but in many places are so close together their bearing powers are greatly decreased. The men can not be induced to thin them out, having a very strong, if not actually superstitious, antipathy to cutting down or injuring a coconut tree. The palm provides not only refreshing drink, while the fruit is green, and food when it is ripe, but a large proportion of the materials used in buildings and their furnishings. There are extensive groves of bamboo on Mer, which are of great value, furnishing as they do the framework for all ordinary buildings and material for innumerable useful articles.

Architecture at Mer is still very simple. Most of the houses are rectangular and contain only one or two rooms. The floor is commonly mother-earth, but in the better class of houses is of bamboo and is well raised above the ground. The poorest houses have only a single doorway and a small, square window opening, but the best have several doors, windows with openings protected by mats, and more or less extensive porches. The bamboo framework of these houses is covered with either a thick layer of coarse grass, put on vertically, each tier overlapping the

THE COURT HOUSE AT MER.

one below, or coconut leaves interwoven and more or less matted together. The roofs are grass thatch. The ugly but convenient and serviceable corrugated iron house, so predominant a feature of tropical Australian towns, has reached Mer, but there are as yet only two examples of it. On the hillside back of Mr. Bruce's home is the school house, a commodious frame building, while only a few steps distant is the church, built in part of wood, but largely of coral rock. The church on Erub is wholly of stone, neatly whitewashed and very picturesque. The most imposing building on Mer is the courthouse. This is situated on the hillside, fifty feet or more above the village on the northwestern side of the island and has a fine outlook over the sea. The walls are entirely of stone, the floor is concrete and the roof is corrugated iron. A veranda surrounds it on all sides. There is a doorway at each end and on each side, and there are a dozen window openings, but doors and windows are wholly lacking. The interior consists of a single room about forty feet long by twenty wide, with a ceiling neatly made of split bamboo rods. This courthouse was cheerfully yielded to us for our laboratory and home during our stay and it served our purpose admirably. The jail near by, built of bamboo, cocoanut leaves and grass, was also placed at our disposal and was useful as a storehouse. Not many Anglo-Saxon communities could give up courthouse and jail for six weeks with no appreciable effect on the social order!

The Miriamites are exponents of the simple life. During the dry season most functions, even of a domestic sort, take place out of doors.

Soon after daylight the daily routine begins. Dressing is not a source of trouble or anxiety. For the smaller children, those under four or five years, it consists of rubbing the eyes, yawning and occasionally a dip in the sea. The older boys and men wear a "lava-lava," the universal costume of South Sea islanders. This is a strip of bright red or blue cotton, usually with white figures, about six feet long by two and a half wide. Its adjustment to the wearer is as simple as the garment itself, for it is wrapped once about the waist and hips, overlapped in front and the upper edge, especially the upper right-hand corner, is rolled and tucked inwards against the body. It is surprising how secure a fastening is thus obtained, and very quickly. On ordinary occasions this is all the clothing men and boys wear, but for church and other dress occasions a white close-fitting shirt is added. The white shirt, contrasted with the dark skin, and the bright lava-lava make a very becoming and picturesque costume. The usual dress for girls and women is a cotton "mother-hubbard," generally dull blue with white dots. This is serviceable, but not ornamental. Shirt waists and wash-dresses are the resource for special occasions, but these rarely have any definite relation to the figure of the wearer. Children and men generally go hatless, but occasionally a hat is a treasured possession and worn when occasion demands. Young women often wear hats to church, but tastes are catholic and there is no close adherence to style. Most of the hats have obviously seen better days.

THE CHURCH AT MER.

Dressing, such as it is, having been completed, breakfast is in order. Baked yams and plantains, with raw bananas or papaw or bits of coconut, with an occasional bit of fish meet the needs of all ages. The fire is built out of doors and the family sit about it on the ground or on mats. Tables and chairs are not wholly unknown luxuries in some of the better homes, but they are not features of ordinary life on Mer. Mats, made from coconut leaves, and surprisingly thick, flexible and soft, are the only furnishings of most houses and replace chairs, lounges and beds quite satisfactorily. Since cooking utensils and dishes are reduced to the lowest terms, little time is required for cleaning up after breakfast, so the members of the household scatter to their various avocations. Some of them may go to the seven-o'clock service at the church, a sort of family prayers for the whole community, not universally attended, but by no means neglected. After this there is a more or less general movement of adults either up to the gardens or out to the reef-flat, while the children flock to the schoolhouse where their intellectual training takes place. They are summoned by the school bell as in a New England village and the antics of the early arrivals correspond closely to those of Anglo-Saxons of a similar age. Educational work is of an elementary character, but the more advanced pupils learn something of the history and geography of the British Empire. Training in neatness, cleanliness and other domestic virtues is emphasized. Mr. Williams, on Erub, has even attempted to train some of the girls in the use of flat-irons, for at the present time all washing is rough-dried.

No formal meal interrupts the day at noon. This does not mean, of course, that no food is eaten at midday, but simply that it is in the nature of a pick-up lunch. If work in the gardens is not pressing, and there is no special call to go fishing, a ball game of a purely informal sort may furnish amusement in the early afternoon. Later on groups of men may be seen sitting about under the trees playing cards! The decks are obviously of some antiquity and no doubt originally came from Thursday Island. We were never able to fathom the game which was played, but it appeared to be a local modification of something which the more travelled men have learned on the pearling boats or at the metropolis. The women do not play, nor do the young people of either sex, but there is no evident gambling connected with the game. The weaving of mats is an occupation very much in evidence, the work being done chiefly by women and old men, though younger men often help in securing and preparing the leaves. The children weave small square or oblong "balls" from the strips of leaf, with which they have much sport. These balls are very light and are tossed about like shuttlecocks. They are made with remarkable neatness and when fresh and clean are often very pretty. Late in the afternoon the women begin to

light the fires and prepare the evening meal, which does not greatly differ from breakfast, save that it is usually heartier. Fish, turtle-meat or eggs may be the chief item and if plentiful may transform supper into an "aule kaikai." After supper, conversation, story-telling and joking occupy the groups sitting about the fires, and frequently dances occur in which either the men alone, or both sexes, indulge. The dancing is anything but graceful and seems clumsy and unattractive, but it is not ordinarily objectionable in any way. The Miriamites retire early and except for occasional parties, fishing by torch-light on the reef-flat, the peaceful quiet of night settles down upon the island by nine o'clock.

Isolated as they are, the communities of Miriamites on Erub and Mer will probably continue to lead their simple lives for many a year, protected by the paternal care of Queensland. Their material resources are too insignificant to be a source of danger from the covetous whites, while they lie too far from any possible commercial route to make industrial development by the natives themselves probable. Four times in the past twenty-five years parties of scientists have sojourned at Mer, to study either the people or the fauna of the islands, and no doubt similar parties will visit them in the future. But these visits will not be frequent enough or sufficiently prolonged to affect in any considerable degree the language or the essential characteristics of the people. If the Queensland government can continue to secure men like Messrs. Bruce and Williams to teach and care for these child-like people, there is no obvious reason why the Miriamites should not persist in their lovely little islands for centuries to come.

THE TOP OF THE ISLAND, MER.

THE EVOLUTION OF FLOWERS

By JOHN H. LOVELL

WALDOBORO, MAINE

WHAT is a flower? This would seem to be an easy question for a botanist to answer; but, as a matter of fact, the definitions differ widely, and it has even been asserted that a strict definition is impossible. According to the German morphologist, Goebel, a flower is simply "an axis bearing sporophylls," that is, a stem with one or more modified leaves bearing spores. The fructifications of the horsetails and club-mosses would thus be regarded as flowers. This extension of the term is certainly not without its advantages, since it calls attention to the very ancient origin of floral structure and to its beginning among the primitive forms of plant life; but the strobili of the Pteridophytes are so unlike those of the Angiosperms and are so much older that to call both flowers is likely to prove confusing. Asa Gray and the older morphologists often speak of "the flowers" of the Gymnosperms; but the open carpel without style or stigma, as well as a difference of opinion in the case of several groups as to what constitutes a flower and what an inflorescence, are objections to this usage. Consequently it has been proposed to restrict the word flower to the Angiosperms, plants with a closed carpel, a part of which is specialized for receiving pollen. The term, as thus limited, has a very definite meaning, which can not be easily misunderstood even when the flower is reduced to a single stamen or pistil as among the aroids. This definition has also the advantage that it agrees with the popular conception of the word; and where possible for obvious reasons it is desirable that the definitions of science and of the non-scientific public should agree. The Angiosperms have been well called the Anthophyta, or flower-plants.

In the history of the evolution of plants the origin of the Angiosperms still remains an unsolved mystery. This great series makes its appearance suddenly in the Lower Cretaceous; and the fossil species exhibit no intermediate or transition stages, but possess all the essential characters of their modern representatives. There are a variety of comprehensive forms, it is true, which have been termed Proangiosperms; but there is no certainty that any of them are the actual precursors from which sprang the plants with a closed carpel. If, however, the Proangiosperms *de factu* were trees, as has been strongly advocated, there is good reason to hope that this knowledge will not always remain a secret of the rocks. But for the present any attempt to trace the

phylogeny of the Angiosperms must rest largely upon comparative morphology and conjecture; and so great is the fascination the problem offers that it is no exaggeration to say that every probable and improbable guess has been exhausted.

Vines formerly advanced the opinion that the Dicotyledons were descended from the conifers and the Monocotyledons from the cycads. Miss Benson, Hallier and Karsten have endeavored to trace back the Angiosperms, through the ament-bearing trees (Amentaceæ), to *Gnetum* of the Gnetales, an aberrant group of Gymnosperms. Campbell has suggested that the Monocotyledons may be connected with forms like *Isoetes,* as both have a single first leaf, and there are resemblances in the anatomical structure of the stem, leaf and root; but, he adds, that there is an immense interval between the simplest angiospermous flower and the sporophylls of *Isoetes.* Coulter has pointed out that *Selaginella* in its dicotyledonous embryo and the resemblance of the megasporangium to the seed condition is as suggestive of the Dicotyledons as *Isoetes* of the Monocotyledons; but an independent origin of both groups from *Marattia*-like ferns is favored. Others would reject a derivation both from the Gymnosperms and fernworts and seek for the beginning of the Angiosperms among the Bryophytes, or as a wholly independent phylum arising from the Algæ—one highly imaginative theorist, for instance, would derive the higher seed plants from the liverworts through apospory.

If these widely ranging speculations, of which only a very few are cited here, prove anything, it is that at the present time it is futile to look for the origin of the Angiosperms outside of the Gymnosperms. If they have come from a more primitive source, then we must be content to wait until the geological record shall be further revealed. As for the Gymnosperms themselves, it is established with reasonable certainty that they are descended from the Pteridophytes; and that their evolution extended over a long period of time, during which a great number of species became extinct. During the Mesozoic Age more especially in the Triassic, a remarkably equable climate prevailed over a large extent of the land surface of the globe, and gymnospermous trees were the dominant forms of plant life; conifers, maidenhair trees, cycads and cycadophytes in the greatest variety multiplied and developed every possible combination of cone structure. These vast forests must have displayed a foliage which in beauty of form has never been equalled, either before or since, in a terrestrial landscape. To suppose that contemporaneously another great phylum, which gave birth to the Angiosperms, was in existence, but of which not a vestige has been discovered, seems at least improbable. The morphological differences between the Angiosperms and the Gymnosperms, it is true, are so great that there is a strong tendency to regard them as entirely independent, nevertheless

the affinities between these two great series are much closer than between the Angiosperms and the Pteridophytes, *e. g.*, there can be no doubt, as Jeffrey insists:

> That the argument for descent from the Gymnosperms seems to gain great force from the entire absence of fernwort characters in the shorter leaves of the Angiosperms.

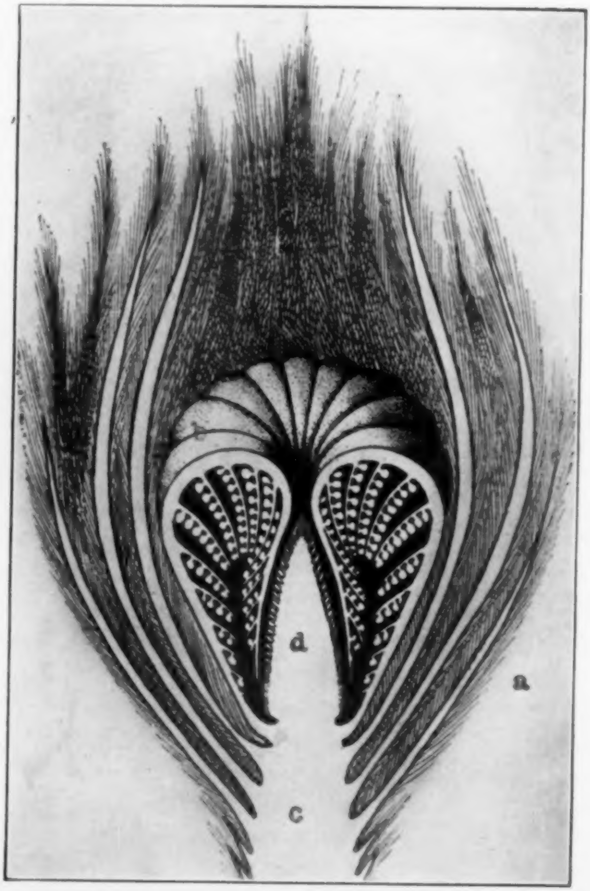

DIAGRAM OF STROBILUS OF *Cycadeoidea dacotensis*. (After Wieland.) *a*, hairy sheathing bracts; *b*, folded stamens; *c*, elongated axis; *d*, conical mass of sterile and fertile scales.

A few years ago the gymnospermous origin of the Angiosperms was temporarily believed by many to have been fully established when Wieland published his description of the bisporangiate cone of *Cycadeoidea dacotensis,* a fossil plant belonging to the extinct order Bennettitales. It was not supposed that *Cycadeoidea* was the direct ancestor of

the Angiosperms, but that the structure of its strobilus furnished decisive evidence of their derivation from an allied group as yet undiscovered. It was confidently hoped that the baffling mystery of the descent of the Anthophytes was about to be solved; and Arber and Parkin, taking Wieland's investigations as the basis of their work, sought to reconstruct the ancestral type of such flowers as *Magnolia.* The characters of the strobilus of *Cycadeoidea,* in the opinion of Scott, justify the conclusion that the Bennettitales were, of all known plants, the most nearly akin to the Angiosperms. The fructification of *Cycadeoidea,* which created a genuine sensation in the botanical world, must thus be regarded as the most interesting "flower" known to-day.

The strobilus of *Cycadeoidea,* as described by Wieland (see Fig. 1), was nearly five inches in length, with an elongated axis on which all the floral members, except the stamens, were spirally inserted. A series of densely hairy sheathing bracts, about three inches long, represented a primitive perianth. The bipinnate, frond-like stamens were united at base into a disc, and on the numerous pinnae there were two rows of pollen-sacs. The apex of the conical axis, prolonged above the stamens, was covered with a mass of fertile and sterile scales. The fertile scales were reduced to long slender stalks bearing terminal seeds containing dicotyledonous embryos. The interseminal sterile scales were club-shaped at the end and united by their distal edges into an envelope resembling a pericarp with a small central orifice out of which projected the micropyle, or open end of the seed. The flowers were anemophilous and the pollen came directly in contact with the seeds as in other Gymnosperms. If the large cones of this species, or of other Cycadophytes, displayed dull red or purple coloration, as is the case with many modern conifers and cycads, the Mesozoic forests were not entirely a somber monotonous green as is commonly supposed.

Guided by the strobilus of *Cycadeoidea* Arber and Parkin have endeavored to reconstruct the prototype of an angiospermous flower like *Magnolia.* This hypothetical "flower," or strobilus, is supposed to have been of large size, solitary, with the members spirally arranged on an elongated axis. The perianth was composed of an indefinite number of leaf-like bracts, which were probably green in color. The staminate organs may have been bi-pinnate fronds bearing two rows of pollen sacs upon the lateral leaflets; but it is more probable that they were very much reduced in size and that the lateral pinnæ had disappeared,—fossil stamens of a *Williamsonia* found by Wieland in Mexico had the number of pollen sacs reduced to two. The central fertile scales were broad, short leaves bearing a few ovules on their margins, a primitive stage still preserved by the carpellary leaf of *Cycas.* The strobili were pollinated by the wind as in all other Gymnosperms of this age. The effective

factor in transforming this ancestral form into a flower like *Magnolia,* according to Arber and Parkin, was the establishment of entomophily or insect visits. From this assumed prototype a *Magnolia* flower differs chiefly in that the stamens have lost their leaf-like character and bear only two anthers, while the open carpels have folded over the seeds and the pollen is received on a stigmatic surface. To both types are common the large size, the elongated axis and the spiral arrangement of the organs, except in the perianth of *Magnolia,* where the cyclic order might easily have been derived from the spiral.

In whatever light this hypothesis may be regarded, it is, at least, certain that the fossil *Cycadeoidea* never gave rise to an angiospermous species. The foliage alone presents almost insuperable difficulty, for while the Cycadophytes had simple bulbous or columnar trunks, surmounted by a crown of fern-like leaves, the Angiosperms branch freely and are microphyllous. Insects could not have been instrumental in bringing about such a transition; and Arber and Parkin endeavor to bridge the difficulty by the improbable supposition of a saltation or mutation. It is much more probable that the varied foliage of the Angiosperms finds an explanation in its physiological significance. Neither does the internal anatomy nor the structure of the gametophytes, according to Jeffrey, lend support to such a relationship. The carpel of *Cycadeoidea* is as truly gymnospermous as that of the cycads or conifers and is even more reduced, remaining only as a slender stalk; while the so-called pericarp, formed by the sterile scales, is not at all homologous with the closed carpel of the Angiosperms. But undoubtedly the strobili of the Bennettitales are helpful in suggesting the structure of the veritable Proangiosperms, which appear to be at present wholly unknown.

As already stated, Arber and Parkin regard the establishment of entomophily as "the motive force," which called the Angiosperms into existence and laid the foundation of their future prosperity. Scott likewise holds "that the rise and progress of the Angiosperms was probably due, above everything else, to their adaptation to the contemporary insect life." This is the generally accepted view, from which there seems to have been expressed no difference of opinion; but it is noteworthy that this theory was advanced chiefly by paleobotanists without extensive field experience in the observation of the phenomena of flower pollination. The reciprocal relations of flowers and insects are often truly wonderful and floroecology doubtless embraces more of romance than any other branch of botany. Entomophily could hardly fail to make a deep impression on the imagination of phylogenists in search of "motive forces"; but in the writer's opinion as a factor in the development of angiospermy it has been greatly overworked and forced to bear a burden greater than it can carry. As a matter of fact there probably were no insects deserving to be called anthophilous contemporaneous

with the beginning of the higher seed plants. Angiospermy must have arisen previous to the Cretaceous; and in the Cretaceous rocks the remains of very few insects have been found, the highest forms in America being those of beetles. As pollinators of flowers the Coleoptera are of little significance; and the development of the entomophilous flora would not have varied in any way in the absence of all anthophilous beetles. There seems to be no reason to suppose that flowers were visited by insects in the Jurassic Age, or that suitable species were in existence. The habit of anthophily was not quickly established; and it was long after the appearance of the primitive Angiosperms that the bees and butterflies were evolved.

But assuming, for the sake of argument, that there were anthophilous insects contemporaneous with the wind-pollinated Proangiosperms, let us inquire whether they could have induced the closing of the carpel. *Welwitschia,* a genus of the Gnetales, is entomophilous, but it still remains a Gymnosperm. If there are African cycads pollinated by insects, as Scott thinks probable, it has not led to angiospermy; nor is there any tendency toward such a modification in several living conifers which are frequently visited by beetles for pollen. Neither would the sporadic visits of unspecialized insects to the progenitors of the Angiosperms have been likely to have resulted in the development of angiospermy. The primitive open carpel must have been either uniovulate or multiovulate. If it were multiovulate then so long as it remained unclosed wind-pollination would have been more effective than insect-pollination, since the wind would be more likely to bring the requisite amount of pollen to many naked ovules than to a small stigmatic surface. The wind would also be a more reliable agent than the erratic visits of primeval insects, which might very rarely come in contact with the ovules of large strobili or of monosporangiate cones. In the case of the multiovulate carpel, so far as pollination in this age was concerned, the advantage would be greatly on the side of the open carpel and anemophily.

If, however, the carpel were uniovulate then obviously it could be equally well pollinated by the wind or insects, whether closed or open, indeed a lobed papillose stigma would offer a larger surface to the wind than would the micropyle of a single ovule. The inclosing of the carpel would here be independent of the question of pollination. For this reason the writer believes that the proangiospermous carpel was uniovulate, as it still is in many anemophilous and entomophilous primitive Angiosperms, *e. g.,* the wind-pollinated grasses and sedges, and largely in the Amentaceæ, and in the entomophilous *Alisma, Ranunculus* and *Fragaria.* In this connection it is noteworthy that the achenes of the Compositæ are one-seeded. The wide occurrence of uniovulate carpels among living Angiosperms would indicate that it was the prevalent

condition among the Proangiosperms, a conclusion supported by the commonness of carpels with a single ovule among the Gymnosperms. If the reverse had been true, it is highly improbable that the number of ovules would have been reduced after the establishment of entomophily; in the Ranunculaceæ the carpels of the primitive genus *Ranunculus* are uniovulate, while in the more highly specialized and later evolved genera *Aquilegia, Delphinium* and *Aconitum,* which are pollinated by bumblebees, the carpels are many seeded. One of the conditions, we hold, then on which the rise of Angiospermy was dependent was the uniovulate open carpel, which was equally well pollinated by the wind or by insects.

The rise of angiospermy was, therefore, independent of insects antedating the appearance of the anthophilous species, the visits of which did not become important until the higher seed plants were fully differentiated and the fundamental characters of foliage and flower determined. If the great plant groups the Cycadofilacales, Cordaitales, Cycadales, Bennettitales and Coniferales were successively evolved under anemophily, there is no inherent improbability in the Angiosperms also originating under wind-pollination.

Since the infolding of an uniovulate open carpel would be of no special benefit in pollination, and angiospermy has not been induced by entomophily it is very pertinent to inquire, in response to what conditions is it a reaction? It is undoubtedly one of the many structures, which have been developed to afford protection to the ovules and seeds in their various stages of growth. Cowles says:

> Adequate protection is especially important in monocarpic species, above all in annuals, since the maintenance of the species depends absolutely upon the viability of its seeds.

Throughout the spermatophytes the need of protection to the seeds is constantly emphasized. In the Cycadofilacales, where the ovules were borne directly on the margin of the sporophyll, they were often enclosed in husks or cupules. In the Cycadales, with the exception of *Cycas,* they are covered by the closely appressed cone-scales; while in *Cycadeoidea* protection was afforded by sterile, club-shaped, interseminal scales. In the Coniferales the seeds are on aborted shoots in the axils of the cone-scales, an advantage of so much importance that Saporta and Marion attribute the existence of the conifers to the development of the cone. Although Arber and Parkin regard angiospermy as a response to entomophily, they at the same time recognize that the closed carpel offers effective protection to the developing ovules. In the Proangiosperms small, uniovulate, open carpels were crowded on the apex of an elongated axis, as in *Magnolia,* where protection to the nascent ovules was most readily secured by the infolding of the carpel.

The involution of the carpel offers in itself very little difficulty, and there are numerous petals and leaves, which regularly or occasionally illustrate the origin of this modification. Abnormal cohesion of the margins of leaves is not unusual, and has been observed in the genera *Tilia, Corylus, Pelargonium* and *Antirrhinum,* and in the leaflets of the rose and strawberry. Phyllody of the pistils or their reversion to open leaves bearing ovules on their margins has likewise been recorded of many species. The protection of nectar from rain or useless insects has given rise to a great variety of tubular petals. In *Ranunculus auricomus* every intermediate stage between the open petal and the tubular nectary occurs; and in *Eranthis hyemalis* there is present a series of transitions between the outer flat perianth segments and tubular petals. Tubular petals are in some flowers the normal condition as in *Helleborus;* and they may occur where this form is apparently useless. Changes from strap-shaped to tubular corollas may often be observed in the marigold and aster; while in *Coreopsis tinctoria* one variety regularly has the rays tubular. In a variety of *Papaver bracteatum* the petals cohere to form a gamopetalous corolla. Undoubtedly tubular nectaries have been developed independently in widely separated families; and it is not improbable that angiospermy may have originated more than once. The carpel did not at first close entirely, but the apex was filled with a mucilaginous liquid, which served to retain the pollen until the development of a stigmatic surface—such a mucilaginous drop is found in the micropyle of coniferous ovules. The subsequent development of the style permitted the relative position of the stigma to be changed; the filaments performing a similar service for the anthers.

How long an interval elapsed after the origin of angiospermy before entomophily was established it is impossible to say; but the evolution of the bees, or Anthophila, the most important of all the anthophilous groups, must have been a comparatively modern event. The first flower-visiting insects were synthetic types without special adaptations for gathering pollen or nectar; and their attentions were, of course, forced upon flowers and not the result of allurements offered to secure their services. In the writer's opinion pollen was the first source of attraction. To suppose that the fructifications of the Proangiosperms contained nectar is purely an assumption, since there is no reason to believe that the strobili of the anemophilous Gymnosperms were ever nectariferous, or that nectar was common in flowers until after the rise of entomophily. Moreover, an examination of anthophilous insects shows that they became progressively specialized from pollen-eaters to nectar-feeders. Of the beetles seeking flower food *Trichius affinis, Euphoria inda* and various Coccinellidæ manifest a preference for pollen; while the genera *Nemognatha* and *Gnathium* live wholly on nectar, for procuring which the maxillæ have become modified into a suctorial tube.

Among Diptera the Syrphidæ and Muscidæ consume both pollen and nectar, while the Bombylidæ and Empididæ feed entirely on nectar. The short-tongued bees belonging to the genera *Prosopis, Sphecodes, Halictus* and *Andrena* still eat pollen; but adult honey-bees are wholly dependent on honey, and in its absence a colony will starve although there is an abundance of pollen in the combs. The evidence favors the view that anthophilous insects began by eating pollen, and that the secretion of nectar and its use as a food were events of later date. In their relations to a floral diet, adult beetles and flies may be divided into four groups: (1) species which never visit flowers or only accidentally; (2) species which are partly predaceous or phytophagous and partly anthophilous; (3) species which live on pollen and nectar exclusively; (4) species which live on nectar alone.

The pollen of anemophilous flowers is still gathered by both the smaller and larger bees and devoured by beetles and flies. According to Henslow there is no pollen grain so smooth that the hairs on the limbs of a bee or fly can not hold it, even the pollen grains of grasses, though smooth in water, when dry are notably wrinkled into sharply angled and irregular shapes. Small Syrphid flies have been observed by the writer resorting regularly in the morning to the flowers of the common herd's grass for the purpose of feeding on the pollen. While honey-bees to-day more often gather pollen from anemophilous flowers than the solitary wild bees, this is obviously an artificial relation incidental to the many large apiaries maintained for the production of honey and wax, which contain thousands of workers and require immense quantities of pollen for brood-rearing. At the time of the beginning of entomophily the Anthophila were not in existence. Unlike all other tribes of insects, the bees are wholly dependent on pollen for brood-rearing, and the acquisition of this habit must have been an important factor in determining the course of their development. The pollen of entomophilous flowers has acquired adhesiveness and a rough or spinose surface, which greatly facilitates its transfer by insects from one flower to another.

While insects were first attracted to flowers by pollen, nectar secretion offered a stronger allurement and gave a new impulse to entomophily. Nectaries occur on the foliage of a great variety of plants, even on the stalks of ferns (*Pteris*), as well as in flowers; and its secretion is primarily a function independent of insects. Leaves secrete and excrete a great variety of products, and besides nectar glands may possess water-glands, chalk-glands and slime-glands. Since transitions between water-glands and nectar-glands occur, it can not be certainly affirmed, says Cowles, that the secretion of nectar by leaves is other than a waste product. The appearance of nectar-glands, at least occasionally, on the modified leaves of entomophilus flowers would be wholly in accordance with expectation; and their value in attracting insects would ensure

their preservation. The need of protection from wet and robber insects subsequently resulted in the development of nectaries. In more recent times this function in my opinion has been lost by various pollen flowers, as *Anemone, Rosa* and *Desmodium,* and nearly so by the mulleins.

Besides an adhesive pollen and nectar secretion there are correlated with entomophily bright coloration, attractive odors, and a great variety of mechanisms for the transfer of pollen through insect agency. Except to a very limited extent these characters do not belong to wind-pollinated flowers, and in the absence of insects there is no satisfactory evidence that they would have ever been developed. On the contrary with the cessation of insect-visits they may be speedily lost and the flowers revert to anemophily, as in *Artemisia.* Among the older floroecologists it was practically the universal belief that the structural modifications enumerated were purposive adaptations to ensure cross-pollination. Adaptation in this sense is now regarded as akin to vitalism and its validity denied. It may be admitted that plants do not possess an inherent power of producing structures because they are needed, that natural selection has been given too wide an application, that other factors have been important in the development of flowers, as orthogenesis, mutation and, in view of the probability that many species are hybrids, as held by Lotsy and Jeffrey, Mendelian laws of inheritance. But while many minor and extreme structures of flowers may be due to special factors, the hypothesis that the general trend of floral evolution has been determined by the preservation of advantageous variations, whatever their origin, by natural selection offers the field ecologist a tenable working theory better than any other available.

Difficult as is the problem of the origin of flowers, a solution is far from hopeless.

> By past efforts unavailing,
> Doubt and error, loss and failing,
> Of our weakness made aware,

there is nevertheless no other course left for the phylogenist than to continue "trying with uncertain key door by door of mystery." The great success of the paleobotanist in tracing the descent of the Gymnosperms awakens the hope that fossil records will yet be discovered, which will throw new light on the evolution of the Anthophytes. Let us await the testimony of the rocks.

THE ELECTROMAGNETIC THEORY OF LIGHT

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OF the many striking advances which marked the progress of physical science in the past century, two stand out as preeminently the greatest and most far-reaching—the discovery of the principle of the conservation of energy, and the promulgation and verification of the electromagnetic theory of light. Many other discoveries of the highest interest and greatest value were made, but these two stand apart as the crowning achievements of nineteenth-century physics. While a knowledge of the former of these principles has become widely diffused, we find quite the reverse to be true with regard to the latter. The "conservation of energy" has become a household phrase, while, on the other hand, there are very few to whom the "electromagnetic theory of light" is more than a meaningless expression. This lack of acquaintance on the part of the general public with one of the most interesting developments of modern scientific theory is doubtless due in large part to the fact that there has been little attempt up to the present time to present the essentials of the theory in simple form and in non-mathematical language, so as to be readily intelligible to the average well-informed reader. The story of the successive steps in the development of the theory and of the various experiments which have served to establish it on a firm basis forms one of the most fascinating chapters in the annals of modern science, and it is the purpose of the present article to recount the chief of these steps as well as to outline briefly the essential features of the theory.

The speculations of the ancients as to the nature of light strike our modern fancy as fantastic and grotesque. Many of the philosophers of antiquity advocated the view that we see bodies by means of rays proceeding from the eye to the object of vision rather than in the contrary direction. None of the theories proposed rested upon any basis of scientific fact. The first serious attempt to answer the question as to the nature of light seems to have been in the time of Newton. At this time two conflicting theories arose; the corpuscular theory, and the undulatory, or wave, theory.

Those who held to the former theory advocated the view that luminous bodies are continually emitting streams of small particles traveling with very high velocity, like tiny bullets, which, on entering the eye, produce the sensation of sight. Simple though the theory may appear at first sight, it was soon found that in its general application diffi-

culties are encountered which can only be surmounted by resorting to hypotheses which seem extremely strained and artificial. Newton himself stood sponsor for the corpuscular theory, and it is evident that the weight of his opinion maintained it in the ascendancy much longer than if it had been left to stand or fall on its own merits. Until the close of the eighteenth century this was the theory generally accepted.

The wave theory, according to which light consists of waves traveling through a medium of some sort rather than a stream of material particles, was elaborated by Newton's contemporary, Huyghens, and in many respects seemed more closely in accord with the results of experimental evidence than the corpuscular theory. At that time, however, positive evidence serving to discriminate between the two theories was lacking. Such evidence was furnished many years later by the establishment of the fact that light travels more slowly in dense than in rare media; a result in accord with the predictions of the wave theory, but directly opposed to the consequences to which the corpuscular theory would lead us. This evidence was not available in the seventeenth century, however, as no practicable method of determining the velocity of light in different media had been devised at that time. Newton seems to have been led to reject the wave theory because of the fact that light does not appear to bend around the corners of an obstacle as do sound waves or water waves. This premise we now know to have been a mistaken one, for the beautiful diffraction experiments of Fresnel proved that light does bend around the edges of a body as do other types of waves. The effect is less noticeable the shorter the length of the wave, however, and in the case of light waves is only rendered manifest by such phenomena as those of diffraction. Finally, in 1801 the wave theory became definitely established through the classic experiments of Thomas Young on interference.

To have proved that light consists of waves, however, is to have advanced only a short way toward the complete solution of the problem. It is at least equally important to settle the question as to what kind of waves light waves are. In every type of wave motion it is essential that we have a medium and a disturbance of some sort traveling through this medium. So we have not learned much as to the true nature of light until we are able to give some account of the nature of the medium which serves to convey light waves and of the character of the disturbances which are set up in it.

The questions as to the nature of the medium and the character of the disturbances are linked closely together, for upon the properties of the medium will naturally depend the type of disturbance which that medium is capable of transmitting. Certain properties of the medium which must be supposed to exist in order to account for the phenomena of light were manifest from the first; certain characteristics which

made it evident that the medium in question must differ in many respects from ordinary matter. It must fill all space and at the same time must be tenuous in the extreme, since the planets and other heavenly bodies move through it without having their motion retarded in the slightest degree. It must also be capable of acquiring and transmitting energy, both potential and kinetic. To this medium was applied the name "the luminiferous ether."

One of the most common types of wave motion is that found in elastic solid bodies, and in many respects there seemed to be a similarity between light waves and the waves in such bodies. Accordingly, the "elastic solid theory" arose, which attributed to the ether the properties of an elastic solid and assumed that ether waves were similar to the waves set up in bodies of this character. The properties of such waves are familiar and their velocity can always be expressed as a function of the density and of the elasticity of the medium. The theory furnished a simple and satisfactory explanation of the majority of optical phenomena and seemed a long step toward the solution of the problem as to the nature of light.

There were certain implications of the theory, however, which seemed to necessitate somewhat violent assumptions as to the properties of the ether. The velocity of waves in elastic bodies is $\sqrt{E/d}$, where E represents the elastic modulus of the medium and d its density. Now since light travels through the ether at the enormous velocity of 300,000 km. per second, it follows that E must be very great or d extraordinarily small. But the assumption of a medium with density far below that of any known material substance, and at the same time with elastic properties comparable with those of steel, involves obvious difficulties. Nor was this the chief difficulty. The phenomena of polarized light proved beyond a doubt that light waves are transverse waves. Nowhere was there any evidence of the existence of longitudinal waves in the ether. An elastic solid, however, must be capable of transmitting either longitudinal or transverse waves. So various theories were proposed to account for the absence of longitudinal ether waves, one of the most prominent being Lord Kelvin's "labile ether," which was supposed to have a negative elastic modulus, and which, if not supported in some manner at the outer boundary, would tend to contract. But all these theories were more or less artificial, and none of them seemed to furnish a satisfactory solution of the difficulties which they were designed to remove.

From a study of the phenomena of electricity and magnetism evidence was accumulating that a non-material medium must be invoked to account for the fundamental facts in those fields also, but there was nothing to show that the medium which served as the basis for electrical and magnetic forces was identical with the "luminiferous ether," nor

had the study of these phenomena thrown any light on the problems which had arisen with regard to the nature of the ether.

Such was the state of affairs when James Clerk Maxwell, in 1864, by a supreme stroke of genius, advanced the theory which has served to link together two great branches of physical science and to bring order out of a chaos of apparently unrelated facts. Proceeding upon a basis of facts derived from a study of electrical and magnetic phenomena (a foundation laid for the most part by Faraday), Maxwell showed that electromagnetic disturbances, originating at any point in space, should be propagated in all directions through the ether, not instantaneously, but with a finite velocity which could be calculated by means of certain equations which he derived. The value of this velocity thus calculated came out 3×10^{10} cm. per second. At once the identity between this figure and the velocity of light as determined by several independent methods was strikingly apparent and led to the suspicion that light might be a disturbance of electromagnetic nature traveling through the ether in accordance with the laws governing such disturbances.

On the basis of this fact alone, however, the agreement between the two figures might be set down as a coincidence—a striking one, it is true, but not beyond the bounds of possibility. But Maxwell went much further than this, and showed that an oscillating electric charge should give rise to a wave motion in the ether answering in all essentials to the known properties of light waves; that these waves, consisting of an alternating electric field accompanied by an alternating magnetic field at right angles to it, and hence known as electromagnetic waves, should in case of incidence on a material medium be either reflected, refracted, or absorbed by that medium, just as light waves are.

Another very important fact was evident from Maxwell's equations —the alternating electric and magnetic fields which constitute the waves are necessarily in a plane perpendicular to the direction in which the waves are advancing; in other words, electromagnetic waves are transverse waves. Now this we have seen to be one of the essential characteristics of light waves and one which can not be satisfactorily explained on the elastic solid theory. By making the assumption that light waves are electromagnetic waves, Maxwell was thus able to account for their transverse character, to explain in a satisfactory manner all the fundamental phenomena of light, and to predict a most striking interrelation between the electrical and the optical properties of a body.

The electromagnetic theory of light as worked out by Maxwell seemed a plausible and, on the whole, a satisfactory solution of the problem as to the nature of light, but it could hardly take its place among the rank of established theories without actual experimental evidence of the existence of electromagnetic waves. Such evidence was not forthcoming until more than twenty years after Maxwell proposed the theory.

In 1888 Heinrich Hertz, in a series of brilliant researches, succeeded in producing electromagnetic waves in the laboratory and in showing that these waves possessed the characteristic properties which Maxwell had predicted. In Hertz's classic experiments two polished knobs, each attached to a rectangular metal plate, were connected to the secondary terminals of an induction coil and brought near each other. When a spark was allowed to pass between them, and a loop of wire with small adjustable spark gap was brought in the neighborhood, a tiny spark was observed in this second and independent circuit. The device for producing the original spark Hertz called the oscillator and the loop of wire the resonator. In order to prove that the effect observed was due to the radiation of some form of wave motion from the oscillator, Hertz formed stationary waves by placing a large metallic plate at some distance from the oscillator, and on moving the resonator gradually from the oscillator to the plate, found that the effect showed well-marked maxima and minima at regular intervals. A spark discharge such as is obtained in Hertz's oscillator has been shown to be oscillatory in character, and it is apparent from the experiment just described that such an oscillatory discharge sets up a wave motion of an electrical nature in the surrounding space which is reflected from the metal plate, resulting in the formation of stationary waves. By measuring the distance between successive "nodes" Hertz was able to determine the wave-length of the waves; from the dimensions and other characteristics of the oscillator it is possible to ascertain the frequency of vibration; then, knowing that in any type of wave motion the velocity is equal to the product of the frequency and the wave-length, it may be proven that the velocity of these electrical waves is 3×10^{10} cm. per second, the same as the velocity of light. Hertz showed that these waves, which were evidently the electromagnetic waves predicted by Maxwell, could be reflected, refracted and polarized; that they exhibited the phenomenon of interference; in short, that they possessed all the characteristic properties of light waves, the only difference between these waves and those which affect the optic nerve being a difference in wave-length. From a practical standpoint Hertz's discovery was of the utmost importance, for it marked the inception of modern wireless telegraphy. Other important consequences of the electromagnetic theory, which will be described presently, were confirmed later, but the original work of Hertz was sufficient to show that Maxwell's theory was in thorough accord with experimental evidence and thus to place the theory on a firm basis.

Before going further into the implications of the theory, let us see just what it postulates as to the nature of light. It is a familiar fact that a changing magnetic field gives rise to an induced electromotive force at right angles to its own direction. It is equally well known that

an electric current, or what amounts to the same thing, the motion of lines of electric force, sets up a magnetic field at right angles to the direction of these lines. An alternating electric field is then necessarily accompanied by an alternating magnetic field perpendicular to itself, and vice versa, each field attaining its maximum while the other is passing through its zero value. An electric charge at rest is surrounded by a stationary electric field; if it is caused to oscillate, it sets up an oscillating electric field at every point in the surrounding space, accompanied by an oscillating magnetic field at right angles to it. These electrical and magnetic disturbances travel outward in all directions through the ether at the enormous velocity of 300,000 km. per second, the electrical and magnetic fields being always at right angles to the direction in which the disturbance is traveling. The higher the frequency of the oscillations, the shorter will be the distance between two successive disturbances, or the wave-length. Only when the oscillations are taking place at an extremely rapid rate does the length of the waves become short enough for them to affect the human eye. Such is our conception of a light wave on the electromagnetic theory.[1]

The vast importance of the part which electromagnetic waves play in nature may be appreciated from the fact that within the group are included the entire range of radiations known as X-rays, gamma rays, ultra-violet rays, visible light of various colors, infra-red rays, heat waves, and the long waves used in wireless telegraphy. The inclusion of the first-named rays within the group must be counted one of the most remarkable achievements of experimental science in the present decade. The researches of Laue, the Braggs, and Moseley on the diffraction of X-rays by crystals have proven that X-rays consist of very short ether waves, having a wave-length of the order of magnitude of an Ångström unit (an Ångström unit being the ten-millionth part of a millimeter). In fact, the most recent work indicates that under certain conditions X-rays may be produced having a wave-length even shorter than a fifth of an Ångström unit. The gamma rays given off

[1] It will be noted that the so-called "displacement currents" which play so prominent a part in Maxwell's development of the theory have not been mentioned. It is difficult to form a clear conception of the exact nature of displacement currents, so that a discussion of them would be out of place in an elementary presentation. Moreover, however important may be their part in the mathematical development of Maxwell's equations, it is at least open to question whether we may not leave them out of account in formulating a statement of the essential characteristics of an electromagnetic wave. For certainly the outstanding features of such a wave are the alternating electric field accompanied by the alternating magnetic field. We are at liberty, if we choose, to invoke displacement currents set up by the electric field as an intermediate stage necessary to the production of the magnetic field, but the electric and magnetic fields are undoubtedly the fundamental facts upon which we are to fix our attention.

by radium and other radio-active bodies, being essentially X-rays, have wave-lengths of the same order of magnitude, but even shorter, the wave-length of the gamma rays being only about one tenth of an Ångström unit. Between the X-rays and the shortest ultra-violet rays so far obtained lies a gap, as yet unexplored. The region of very short waves of ultra-violet light, first investigated by Schumann, has been greatly extended toward the short wave-lengths by Lyman, who has been carrying on some notable work in this region and has just succeeded in measuring wave-lengths as short as 600 Ångström units or 0.00006 mm. His success in this field encourages the hope that the limit may be pushed much further and the gap entirely bridged before long. The region of the spectrum lying between 600 and 3,900 Ångström units comprises the ultra-violet rays, so-called because they lie just beyond the violet of the visible spectrum. These rays are entirely invisible to the human eye, but produce chemical action and affect a photographic plate quite readily. From 3,900 to 7,600 Ångström units (0.00039 to 0.00076 mm.) we have the visible spectrum, ranging from violet, the shortest visible rays, to red, the longest. Beyond the red end of the spectrum we have the infra-red rays, which do not affect the eye, but which convey radiant heat and are frequently known as heat waves. It is these waves, together with those of the visible spectrum, which bring to us from the sun the tremendous and unfailing stream of energy without which no life could exist on earth. This region of the spectrum has also been greatly extended in recent years, first by Rubens and his co-workers, using the method of "rest-strahlen," which enabled them to investigate waves as long as 0.06 mm., and more recently by Wood and Rubens, who used the ingenious method of focal isolation, by means of which they succeeded in obtaining the longest infra-red waves so far discovered. The longest waves obtained by this method had a wave-length of about 0.34 mm., while the shortest Hertzian waves, as produced by Righi, measure about 3 mm., leaving an unexplored region of comparatively narrow extent. Then come the electromagnetic waves produced by electrical means and varying in length all the way from the short ones produced by Righi to the very long ones used in radiotelegraphic work. The waves actually employed in this work vary from 100 meters in length or less to 10,000 meters or more.

It follows, then, that the longest known electromagnetic waves are more than one hundred trillion (10^{14}) times as long as the shortest ones. There are few of the facts revealed by the progress of modern science which make a more striking appeal to the imagination than this tremendous range of waves, varying in length all the way from those so small that hundreds of millions of them would be required to cover an inch to those several miles long; all of them essentially the same in character and obeying the same fundamental laws, but affecting us in

different ways according to their length—some of them affecting the optic nerve and revealing to our eyes all of the various colors of nature, some of them conveying to us the heat of the sun, some producing chemical effects or making an impression upon a photographic plate, some penetrating with ease bodies which are opaque to ordinary light, some healing diseases, while yet others serve to bring us messages from the ends of the earth.

It is instructive to vary our point of view by arranging this long scale in octaves, as is done in the case of the musical scale. Upon doing this we find that the whole range covers just about 48 octaves, of which the visible spectrum comprises only one! Starting with the shortest of all, the gamma rays of radium, we have a range of about four octaves, including the gamma rays and the different types of X-rays. Then comes a space of something over nine octaves, as yet unexplored. The ultra-violet group, including the waves studied by Schumann and by Lyman, follows, embracing somewhat less than three octaves. The single octave comprising the visible spectrum is next in order. The infra-red group occupies between eight and nine octaves, followed by a scant three constituting our second unexplored region. The remaining twenty or twenty-one octaves are occupied by the Hertzian waves, only the last seven, however, being made use of in wireless telegraphy. It is encouraging to note the small extent of the two gaps in our scale in comparison with the vast range which we have been able to study. It is not unreasonable to suppose that these two gaps will be entirely bridged in the near future, and that we shall be able to produce and study at will any wave-length desired from the gamma rays to the longest Hertzian waves.

There are many important consequences of the electromagnetic theory which may readily be subjected to experimental test. Chief among these are the intimate relations which according to the theory must exist between the electrical and the optical properties of a body. When waves pass from one medium to another they undergo refraction, the amount of the bending which occurs depending upon the ratio of the velocities of the waves in the two media. This ratio of velocities is termed the index of refraction of the one medium with reference to the other. But according to the electromagnetic theory the velocity of these waves in any medium is equal to $V/\sqrt{e\mu}$, where V represents the velocity of the waves in the ether, e the dielectric constant of the medium and μ its magnetic permeability. We may assume without sensible error that the magnetic permeability of any ordinary transparent medium is unity, from which it follows that $V/V' = \sqrt{e'}/\sqrt{e}$ for any two media. Since the dielectric constant of the ether may be taken as unity, it may readily be seen that the index of refraction of any material medium should be numerically equal to the square root of its dielectric constant. Thus we have an important relation between

the electrical and the optical properties of a medium, which may readily be subjected to experimental test.

In applying this relation to a specific case, however, two important facts must be kept in mind. The index of refraction of a given medium is by no means a constant, but varies with the wave-length, approaching a limiting value in the case of very long waves.[2] Neither is the so-called "dielectric constant" really a constant, as the name implies, but it varies to a certain extent with the frequency of the applied electromotive force. In actual practise it is usually determined by applying a steady electromotive force, while in the case of a light wave the alternating electric field is oscillating with an almost inconceivably high frequency. In view of these facts it is not surprising that there are many cases where the relation does not hold good when the ordinary values of the index of refraction and of the dielectric constant are used. There are several cases, however, in which we have striking agreement, even with the use of the ordinary values, as shown by the following table.

	n	$\sqrt{e}$
Air	1.000294	1.000295
Hydrogen	1.000138	1.000132
Carbon dioxide	1.000449	1.000473
Carbon bisulphide	1.637	1.634
Benzine	1.50	1.54

In the case of many substances which have values for these constants not in accord with the predictions of the theory, using the ordinary values, we find that the agreement becomes striking when we use the value for the index of refraction which applies to very long waves. Thus for water $\sqrt{e}=8.95$ and $n=1.334$, using yellow light. But it has been found by Fleming and Dewar that the index of refraction of water for very long waves is 8.9, approximating closely to the value of $\sqrt{e}$ given above. For flint glass $\sqrt{e}$ lies between 2.6 and 2.8 and $n=1.62$, using yellow light, but for long waves $n=2.6$. So that it seems entirely probable that if we could determine the values of n and e under precisely similar conditions the relation would be exactly verified in every case.

When electromagnetic waves fall upon a body which is a non-conductor of electricity, they are refracted, the amount of deviation which

[2] The variation in the index of refraction with the wave-length may be accounted for by assuming the presence in dielectrics of "bound electrons," having certain natural periods of vibration. When light waves fall upon the body, resonance effects are produced by these electrons which affect the velocity of the waves, the effect naturally being greater the more nearly the period of the waves coincides with those of the electrons. The periods of these electrons may be determined from the position of the absorption bands in the spectrum of the substance, and by modifying our theory to take into account their effect we may derive a dispersion formula which represents the index of refraction of the substance for waves of all lengths.

they suffer depending, as we have seen, upon the electrical and magnetic properties of the body. When they are incident upon a conductor, on the other hand, the alternating electric field causes rapidly alternating currents to flow in the surface of the conductor and these currents quickly absorb the energy of the waves. It is an important consequence of the electromagnetic theory, therefore, that conductors of electricity should be opaque to light and non-conductors transparent. In a general way this prediction is confirmed, for the metals, which are the best conductors we have, are also the substances most opaque to light, while many of the best insulators, such as glass, are quite transparent. Certain crystals, such as tourmaline, conduct electricity better in one direction than in another. In such crystals the transparency to light is found to vary accordingly. Most of the exceptions to the rule are explainable upon obvious grounds. For instance, water, although transparent, is a conductor of electricity under ordinary conditions. Water of absolute purity, however, is one of the best of insulators. The opacity of such non-conductors as wood, paper, etc., is explainable on the ground of lack of homogeneity in structure. Many of these substances, such as hard rubber, which are opaque to ordinary light, are quite transparent to the longer infra-red rays. Another apparent exception is found in the case of electrolytic solutions which are conductors of electricity and yet are transparent. It is to be noted, however, that the carriers of the electric current in this case are ions, having a mass very large in comparison with that of the "free electrons" which are responsible for metallic conduction, that they are consequently unable to respond to the rapid oscillations of the electric field in the electromagnetic wave and the wave is therefore not absorbed. In many cases dielectrics possess "bound" electrons or ions having characteristic periods of vibration; if a wave of precisely this frequency falls upon the substance these ions are set in vibration, thus absorbing the energy of the wave; in this way absorption lines or bands are produced in the spectrum when light is passed through the substance.

Another important consequence of the electromagnetic theory which has been fully confirmed by experiment is that light waves should exert a pressure on objects upon which they fall. Maxwell showed that electromagnetic waves must exert a pressure of definite amount, though quite small, upon a surface which absorbed them, and a pressure of double this amount on a reflecting surface. The amount of this pressure, in the case of the light we receive from the sun, he calculated to be less than a dyne per square meter of surface. On account of the smallness of the effect it eluded observation for a long time, but finally Lebedew, of Moscow, in 1900, succeeded not only in detecting this pressure due to light, but in measuring its amount, which he found to agree, within the limits of experimental error, with the value predicted by

Maxwell, thus affording one of the most notable verifications of the electromagnetic theory so far obtained. Nichols and Hull, in the United States, independently obtained the same result.

But however striking the facts we have cited, there is a link missing in the chain of evidence which supports the theory until we have succeeded in tracing the source of the electromagnetic disturbances which constitute light waves. Hertzian waves are set up by an oscillatory discharge of electricity; but where are we to find the oscillating electric charges which the electromagnetic theory calls for as the source of light waves? For many years after the theory was proposed this question was unanswerable; but with the advent of the electron theory a simple and obvious solution presented itself. According to the electron theory, the atoms of matter, instead of being the ultimate units, as was so long supposed, are made up of much smaller particles called electrons, the electron having a mass equal to about $\frac{1}{1800}$ of that of the hydrogen atom. The electron always carries a negative charge, and instead of being fixed in position is in continual and extremely rapid revolution about the positive nucleus of the atom in much the same way that the planets revolve around the sun in the solar system. Here then we have an oscillating electric charge, which must perforce set up an electromagnetic wave, on a vastly smaller scale, but otherwise the same as that produced by a Hertzian oscillator. It will be readily seen that the vibration frequency of these electrons must be almost inconceivably high, for dividing the velocity of light waves by the wave-length of red light we get for the frequency of vibration of the electron when sending out red light $\frac{3 \times 10^{10}}{7 \times 10^{-5}} = 4.28 \times 10^{14}$, or over four hundred trillion times a second, and similarly for blue light we get eight hundred trillion (8×10^{14}) times a second. When we recall the extreme smallness of the electron, even as compared with the atom, it will be apparent that there is nothing inherently improbable in these enormous values for the vibration frequency, however much they may tax the imagination, for in general the smaller the dimensions of the oscillator, the more rapid are the vibrations which it is capable of executing.

In bodies at ordinary temperatures the vibrations are much slower than this and long heat waves are sent out; as the bodies are heated and the molecules vibrate more rapidly the electrons within the atoms are also set in more rapid vibration and shorter and shorter waves are sent out; finally, when the vibration frequency becomes high enough, visible light is produced. It is a familiar fact that luminous gases give line spectra, indicating that certain definite and characteristic wave-lengths are sent out, whereas incandescent solid and liquid bodies give continuous spectra, all the wave-lengths from red to violet being represented. This is in line with what we should expect on our theory, for the electrons in the molecules of gases are free to vibrate in their natural

periods on account of the relatively long intervals elapsing between molecular collisions; whereas in solid and liquid bodies the electrons are continually being disturbed by the frequent impact of one molecule against another and so vibrate in all possible periods, thus giving rise to a continuous spectrum.

Although the electron theory contributed a great deal toward the establishment of the electromagnetic theory of light in that it indicated a probable source of the electromagnetic waves sent out from luminous bodies, we can hardly claim to have proved that the vibrating electron is the actual source of a light wave until we have actually obtained data as to certain of the most important characteristics of the vibrating source and shown that they are in accord with the data obtained as to similar properties of the electron. This has been achieved through a study of the well-known Zeeman effect. It was shown by Zeeman in 1896 that when a source of light is placed between the poles of a strong electromagnet, the lines in its spectrum break up into more or less complex groups of lines. To take one of the simplest cases, when the spark formed between cadmium electrodes is placed in a strong magnetic field and the light examined spectroscopically, the green line which is always conspicuous in the cadmium spectrum is observed to break up into two lines, one on each side of the normal position of the line, when the light is passed along the direction of the magnetic field; when viewed transversely, a triplet is formed. It may be readily shown that these are exactly the effects we should expect if we assume an electron revolving in an orbit as the source of the light waves. A magnetic field perpendicular to the plane of the revolving electron would cause a slight increase or decrease in the speed of the electron in its circular path, thus causing a slight change in the wave-length emitted with corresponding displacement of the spectrum line. The components into which the lines are broken up are found to be polarized, and by observing the direction of polarization in each component it can be shown that the vibrating source must carry a negative charge; further, by measuring the amount of separation of the components the ratio of the charge to the mass of the vibrating particle may be calculated. The value thus obtained agrees so closely with the corresponding ratio for the electron as obtained by a number of different methods that there is no longer room for doubt that light waves are electromagnetic waves set up by the revolution of the electrons within the atoms of material substances.

We may sum up the principal steps in the development of the electromagnetic theory as follows:

1. Maxwell in 1864 predicted the existence of electromagnetic waves and calculated on the basis of purely electrical data the velocity these waves should have. The resulting value proved to be the same as the velocity of light. These waves he showed should be transverse waves,

and should be capable of being reflected, refracted, and polarized just as light waves are.

2. Hertz in 1888 succeeded in producing these electromagnetic waves experimentally. Their velocity has been found to be 3×10^{10} cm. per second, the same as the velocity of light. By actual experiment Hertz showed that these waves were susceptible of reflection, refraction, and polarization and in all essential properties were identical with light waves.

3. The whole range of electromagnetic waves with which we are familiar extends all the way from the gamma rays of radium to the very long waves used in wireless telegraphy, a range of nearly 50 octaves, with only two comparatively small gaps in the scale. One of these regions of waves as yet undiscovered lies between the longest X-rays and the shortest ultra-violet rays; the other between the longest infra-red rays and the shortest Hertzian waves.

4. The electromagnetic theory calls for a very intimate relationship between the electrical and the optical properties of a body and in many cases experimental investigation gives results in close agreement with the predictions of the theory, as in the case of the connection between the opacity of a medium and its electrical conductivity, and between the index of refraction and the dielectric constant.

5. Maxwell, on the basis of his theory, predicted that light should exert a pressure on objects upon which it falls and calculated the amount of this pressure. This effect has been detected by Lebedew in Russia, and by Nichols and Hull in the United States, and found to be equal in amount to the value predicted by Maxwell.

6. The electron theory first furnished an answer to the problem as to the origin of the electromagnetic disturbances which constitute light waves, indicating the vibrating electron within the atom as the probable source. That this explanation is the correct one has been proven in a striking manner by the Zeeman effect, or resolution of spectral lines when the source of light is placed in a strong magnetic field. By means of measurements of this effect it has been proven that the vibrating source must carry a negative charge and that the amount of this charge is identical with that which the electron is known to possess.

In view of the facts which have been cited we can hardly fail to accord to the electromagnetic theory of light a place of preeminence among the achievements of physical science in the past century. Probably no other theory in the whole field of physics has served to coordinate so large a number of apparently unrelated phenomena. Two of the great branches of physics, electromagnetism and optics, have been made one; our insight into the processes of nature has been vastly broadened; and research in quest of an explanation of the more fundamental problems of optics has been both stimulated and directed by this wonderful theory, which will always stand as an enduring monument to the genius of Maxwell.

THE EXPERIMENTAL METHOD AND SOCIOLOGY

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The Theory and Practise of the Experimental Method

SINCE the time of Comte, sociologists have been searching for a method to apply to the data of society which would yield as positive results as those attained in the realm of physical science. The experimental method has contributed in large measure to the striking achievements of modern science. This method allows us to analyze out relations of cause and effect more rapidly and clearly than by other methods. It permits verification by many observers. It has substituted for unreasonable prejudice a definite sort of proof that has attained sufficient certainty to justify prediction.

Experiment is simply observation under controlled conditions. When observation alone fails to disclose the factors that operate in a given problem, it is necessary for the scientist to resort to experiment. The line between observation and experiment is not a sharp one. Observation tends gradually to take on the character of an experiment.[1] Experiment may be considered to have begun when there is actual human interference with the conditions that determine the phenomenon under observation.[2]

The fundamental rule of the experimental method is to vary only one condition at a time and to maintain all other conditions rigidly constant.[3] There are two good reasons for this procedure: in the first place, if two conditions are varied at one time and an effect is produced, it is not possible to tell which condition is responsible, or whether both have acted jointly; in the second place, when no effect ensues, how can we tell which condition is responsible, or whether one has neutralized the other?[4]

Specific illustrations from the fields of physics, botany and psychology may serve to bring the principle to mind: Newton desired to prove the "equal gravitation of all substances." Since the resistance of the air to pendulums of different bulk and shape varied, it was necessary to reduce this condition to a constant factor before the single force of gravitation could be observed. The desired end was accomplished by the construction of hollow pendulums of equal boxes of wood and of iden-

[1] Westaway, F. W., "Scientific Method," 1912, pp. 196–197.
[2] Bosanquet, "Logic," Vol. II., pp. 144–145.
[3] Westaway, *op. cit.*
[4] Jevons, S., "Principles of Science," p. 423.

tical outward size and shape, hung by equal threads, with centers of oscillation at equal distances from the points of suspension. When these wooden pendulums were filled with equal weights of different substances and vibrated with equal velocity, any subsequent inequality in observed vibration of two pendulums must arise from the only condition which was different, namely, the chemical composition of the substances in the pendulums. Since no inequality was observed, it was concluded that the chemical composition of substances had no appreciable influence upon the force of gravitation.[5]

The botanist endeavors to discover the effects of light upon plant growth and resorts to the experimental method. A glass bell jar is placed over a plant and the growth compared with a plant in a shaded bell jar and another plant without a bell jar. But since the sun heats up the bell jars and the resultant warmth affects growth, it is necessary to shield the jars from the direct rays of the sun. In this way it is possible to exert a considerable degree of control over certain conditions which affect growth.

Experimental psychology began in 1840 with the work of E. H. Weber in sensation. Since then the experimental method has been applied to measuring the will, emotion, desire, feeling, memory, reasoning, attention, association and perception, with notable results.[6]

Sensations are mental processes easily controlled because they are connected with physical stimuli such as light, sound, odor and temperature, which can be readily governed. Taste, for example, is influenced by smell, temperature and touch. Each of these three factors may be controlled. Smell may be practically eliminated by plugging the nostrils with cotton. Temperature and touch may be kept constant by reducing all taste stimuli to liquid form and by maintaining liquids at a constant neutral temperature.[7] In this way the usual varieties of tastes have been reduced to four elementary forms, sweet, bitter, sour and salt. Indeed, when dealing with sensation the "essence of the experiment has consisted in controlling the physical stimuli which produce sensations, and then observing what alterations appear in the field of consciousness."[8]

Experiments in associational reaction have led to interesting results and practical consequences. Words are exhibited through a slit in a screen, and the subject is asked to state as promptly as he can the idea called to mind by the word. The reaction time is measured and recorded. Many tests of this sort determine the fundamental bias of the subject in favor of certain types of association; for example, simple concrete associations or imaginary and romantic combinations. The prin-

[5] "Principia," III., vi; and Jevons, *op. cit.*, pp. 443–444.

[6] Angell, J. R., "Chapters from Modern Psychology," 1912, Ch. III.

[7] *Ibid.*, p. 84.

[8] *Ibid.*, p. 90.

ciple is used more or less successfully in criminal procedure. Alienists and specialists in nervous disorders have had considerable success in using this experimental method to elicit information that is ordinarily repressed by the patient.

One of the most promising fields in which the experimental psychologist is working is the field of animal experimentation. The principle of evolution has established the physical continuity of animal and human life, animal experimentation has furnished evidence for the continuity of mental activity. Experimental psychology has demonstrated the important principle that the learning process in animals is by the trial and error method. All children and most human adults still rely on this fundamental process of mental activity. Shy animals as well as tamed ones have been experimented upon by ingenious methods devised by Professors J. B. Watson, E. L. Thorndike and F. P. Porter. These experiments have shown that animals can learn a highly complex reaction in as few trials as human beings and will remember for weeks at a time.

May not a method which has given such brilliant results in a field so closely allied to social science be successfully applied in sociology? It is the purpose of this paper to briefly outline the difficulty and promise of the experimental method for sociology.

Natural Experiments

Comte conceived of pathological cases as indirect social experiments. Whenever the regular course of a phenomenon is interfered with in any determinate manner, true experimentation takes place, and hence according to this interpretation of experimentation it is not important to have a conscious agent to effect the change. While it may be stated at once that Comte's notion of experimentation in the realm of living things was based upon the limited biological knowledge of his time, his concept of social experiments caused by the action of natural forces upon society has been of considerable suggestiveness for sociology. Under certain natural circumstances physical factors at the basis of social life have been limited, held constant, or the ordinary restraining factors have been removed so that the sociologist need only observe the effects.

Such a natural experiment exists in the Arctic Circle where the Eskimo live an isolated life under conditions of extreme simplicity. Here nature has withdrawn her usual variety of resources in flora and fauna, she has produced a pretty constant color scheme (or rather absence of color), controlled her temperature scale in such a fashion that variation in flora and fauna is repressed, and accomplished the maximum degree of isolation from the rest of mankind. Under these circumstances the struggle for existence is severely simple and the in-

habitants have evolved a remarkable system of adapted ways. The Eskimo, in the course of adapting their architectural methods to the only material at hand—snow—have developed the dome, a most unusual form among primitive peoples. Civilized man cannot better this snow Igloo of the Eskimo and finds it absolutely necessary to adopt other Eskimo ways in the Arctic region.[9] Other adaptations appear in the form of bone snow spectacles, bone bows and skiffs made of skins. In social life adaptations are seen in the absence of commercialism (due to isolation and lack of surplus), the elementary organization of property, the institution of polygamy (due to the high male death-rate), and the custom of patricide (due to scarcity of food). Here the sociologist may observe the effects upon social life of the elimination of many physical conditions considered fundamental in temperate climes.

Nature has performed an interesting experiment in the effects of isolation upon a people of much higher cultural stage. In the southern Appalachian mountains live over a million people who are the direct descendants of the colonial population of America. Here in these isolated valleys remote from the swarming centers of population, they have clung fast to the colonial culture with its spinning wheel and cumbersome hand loom. New ideas, modern inventions, contemporary science have come to revolutionize the life of the rest of the nation, while these quiet folk, serene in their simplicity, have been oblivious to all the rush and worry of new problems. President Frost, of Berea College, calls them "our contemporary ancestors of the South," and they do indeed reproduce the life of colonial times, constituting a natural experiment in the effects of isolation.

Professor Ross has given us a most interesting picture of China.[10] Here is another great natural experiment, but of another type. A strict family tradition has operated to maintain a static standard of living and offset the usual restrictions on the birth-rate, so that the population multiplies without let or hindrance. The result is seen in a striking example of Malthus's law of population. A positive effect is produced in the survival of a stock unusually resistant to disease. Here is a case in which most of the civilized interferences with the principle of natural selection are non-existent, and a rare opportunity is thus afforded to observe the operation of natural selection upon human subjects on a large scale.

Sociologists are only now becoming aware of the great significance of such "natural experiments" for the development of sociological principle. More of such careful observational studies as Nansen's "Eskimo Life," Ross's "Changing Chinese," and Mrs. Gerard's "The Land Beyond the Forest," to mention a few, are needed to fill in the sterile places of sociological theory with scientific data.

[9] Nansen, "Eskimo Life."

[10] "The Changing Chinese."

Experimentation upon Human Beings

But the sociologist can not rely on natural experiments alone to test his hypotheses. Such experiments are infrequent, they are not easy to recognize, are difficult to observe properly and will probably become more and more infrequent as time goes on, because of the standardizing effects of the spread of a more homogeneous culture over the world.

Have direct experiments ever been performed on groups of human beings by human beings? Have certain circumstances of social life ever been controlled or limited by conscious human interference? These questions have both a historical and a contemporary answer.

It may be stated as a truism that just so soon as the sociologist passes from the method of passive observation to active interference with the determining conditions of a social problem, he begins to encounter a stiffening resistance. The social reformer meets objections and obstacles at every step. All sorts of opposition are met by advocates of minimum wage bills, eugenic marriage laws, compulsory vaccination and child labor bills. The people believe that serious questions of individual rights, personal freedom and moral responsibility are involved. It is felt that, while the subject of experiment in physical science is inert and insensitive matter, in the social field the experimenter is dealing with exceedingly complex units capable of great individual suffering if the experiment should go wrong. There is a popular disposition to withhold or question the sanction for an act which puts in the hands of one person, or of a group, an apparently arbitrary control over the welfare and destiny of other assumedly equal human beings. Ideals of individual freedom and the sanctity of human life have been won after generations of struggle, and are regarded as too precious a heritage to abrogate in instances where the outcome is doubtful. The parent who experimented upon his children by limiting their food, strangely clothing them, or keeping them from school and intercourse with other human beings would soon be investigated and perhaps brought to court by the agent of the Society for the Prevention of Cruelty to Children. Certain acts although practised in a spirit of scientific experimentation are nevertheless considered criminal and their authors prosecuted by agencies which seek to preserve social welfare. One may experiment upon plants or insects without encountering moral objections, but just so soon as human life is experimented upon, society reacts unfavorably, either through its unorganized method of public opinion or through its more systematized agencies.

The line between permissible and forbidden subjects of experimentation is not sharply drawn. Experimentation, even for worthy scientific ends, when it affects the lives of higher animals is censured. In fact, there is now systematic opposition in the form of an organization of anti-vivisectionists. Yet the experimental method has nowhere

made more positive contributions to human welfare than in the field of live animal experimentation. The death rate from diphtheria has been reduced by the use of antitoxin from 80 per 100,000 in 1895, to 17 per 100,000 in 1907. Careful experimentation upon animals has given us the anti-meningitis serum which has reduced child mortality from this distressing disease over 50 per cent. Inoculation of children against tuberculosis is now possible because of experiments upon rabbits and guinea pigs. Experimentation upon dogs has given us the beneficent thyroid treatment for cretinism in children. Inoculation against malaria and bone grafting have been made possible by animal experimentation.[11] No harm has been done to social ideals and precious human life has been saved.

Yet in spite of this splendid array of worthy achievements which have reduced the pitiful suffering of innocent little children, there are still undiscriminating individuals who see in all animal experimentation a great moral menace. Such has been the mistaken zeal of these persons in the belief that their efforts are protecting our moral standards, that legitimate and beneficent researches of medical scientists have been hampered.

But where draw the line between experiments on living things and experiments upon human beings? Certainly these cases of animal experimentation are on the border line of moral standards. They form very illuminating illustrations of sincere differences of opinion as to where the end may and may not justify the means. Cases of the "poison squad" method of the military scientists or of other instances in which human individuals voluntarily renounce certain rights and freely submit to experimentation, would seem to grade off into this intermediate region where in connection with live animal experimentation the usual moral standards of the sanctity of life are observed to be border line and uncertain. As a matter of fact, there seems to be a regular evolutionary series of stages in the development of the sanction for experimentation. These stages are related to the character of the subject. The sanction for experimentation on inanimate matter and on plant life is within the personal choice of the scientist, no one questions his right; but just so soon as animal experimentation is reached, particularly in the case of higher animals capable of considerable suffering, the sanction of personal choice is regarded by many people as inadequate; and when human life is reached all people demand that a higher sanction for the act than personal will be obtained.

When individuals freely renounce certain rights and for the benefit of humanity submit to experimentation, society does not feel serious concern and may even recognize their self-sacrifice and heroism. The

[11] Chapin, H. D., "What Animal Experimentation Has Done for Children," *Popular Science Monthly*, Jan., 1915, pp. 55–62.

state alone, of human agencies, seems to possess by common consent the social sanction for mandatory interference with the normal lives of persons. Unless the individual voluntarily renounces his personal rights, none but the state may morally and legally take them from him. Society is the only official sociological experimenter. In the past, the sovereign power over human life wielded by the state has more often been exercised by an aristocratic or plutocratic minority than voluntarily and legally delegated by the people to their chosen representatives or executives. History is replete with illustrations of this fact. Tyrannical governments have experimented endlessly and thoughtlessly with the lives and welfare of the people. It is only in recent times that a democratic organization of governments has permitted the people to control legislative experiments upon human life and social welfare.

The Utopian Community Experiments

But before considering those social experiments sanctioned and attempted by the state, and always characterized by a certain amount of constraint, it will be well to examine a few cases of local community experimentation in which the elements are simple and the results positive.

The associationists of the early nineteenth century, Owen and Fourier, advocated the establishment of communities organized on a more ideal basis than the society of the time and promulgated broad humanitarian plans for the regeneration of mankind.

Robert Owen was a practical and successful manufacturer and his cotton mills at New Lanark, Scotland, were models of the time for all employers who sought the welfare of their operatives as well as efficient business organization. Owen's unquestioned achievements at New Lanark brought him a world-wide reputation and convinced him of the practicability of putting ideals of social reform into every-day life. He firmly believed that "man's character is formed for him by the circumstances that surround him, that he is not a fit subject for praise or blame, and that any general character, good or bad, may be given to the world by applying means which are to a great extent under the control of human governments."[12] Assuming then that, at bottom, human nature is fundamentally good, it only remained to eliminate the restraining bonds and the demoralizing influences of existing society to attain harmonious social relations in an ideal community. Owen thought that the evils of the capitalistic system were due to the restraining effects of private property, orthodox religion, and the existing institution of marriage.[13] The remedy for present evils was, therefore, the abolition of these three institutions.

[12] Robert Dale Owen, *Atlantic Monthly*, 1873.

[13] Lockwood, G. B., "The New Harmony Communities," 1902, p. 63.

It was with full confidence that Owen embarked upon the experiment of putting into practise these social ideals. Early in 1825 he purchased 30,000 acres of fertile land of the Rappite Community at Harmony, Indiana, and rechristened the place New Harmony. There were 3,000 acres of land already under cultivation, fine orchards, eighteen acres of full-bearing vines, a regularly laid-out town of 160 houses with streets at right angles to one another, and a public square with large brick buildings.[14]

Founded on the principles of common ownership of property, an unorthodox religion and a simple marriage relation, as Owen understood them, the New Harmony community of 900 souls started on what was to be an epoch-making experiment in the reconstruction of society. Back of the rich natural endowment stood Owen with his generous fortune, ready to assist. But although well supplied with material things and supported by the unfaltering enthusiasm of Owen, the community came to a disastrous end in 1827.[15] The seamy side of human nature appears to have cropped out from the beginning. The community was a very heterogeneous group of persons from many states of the Union. Petty jealousies and quarrels were the constant order of events. One observer writes:

> The people in the town continued strangers to each other, in spite of all their meetings, their balls, their frequent occasions of congregating in the hall, and all their pretence of cooperation. From the first time I set foot within this little town of one half mile square, I think there is not one within the range of my observations during my traveling in other towns of the United States, where the same number of persons, living together within such a compass for so many months, and daily and hourly passing and repassing each other, were so perfectly strangers, and void of all personal intimacy with each other's feelings, views, situations and, very generally, names.[16]

Witness to this state of affairs is borne by the local newspaper, the *Gazette,* for at one time it makes reference to the fact that, "the most eccentric and violent characters" had left the community. Again it admits that

> the principal thing to be contended with is the character formed by a new country. Families have been here collected without any relation to each other's views and peculiarities. Many of these persons, after their arrival, have been deprived of more or less of their property, and a general system of trading speculation exists among them, each one trying to get the best of the other. Confidence can not, therefore, exist among them, and there is an unreasonable spirit of suspicion prevalent. Inexperience in community enterprises is another great obstacle, and education alone can overcome these difficulties.[17]

14 Macdonald's MSS Collection, quoted by Hinds, W. A., "American Communities," revised ed., 1902, pp. 130–131.

15 Hinds, *op. cit.*, p. 134.

16 Lockwood, *op. cit.*, p. 165.

17 Quoted by Lockwood, pp. 168–170.

In the New Harmony *Gazette* of March 28, 1827, the failure of the experiment is acknowledged in these words:

> Our own opinion is that Robert Owen ascribed too little influence to early anti-social circumstances that had surrounded many of the quickly collected inhabitants of New Harmony before their arrival here, and too much to the circumstances which experience might enable them to create around themselves in the future. He sought to abridge the period of human suffering by an immediate and decisive step, and the plan was boldly conceived; the failure would only afford proof that the conception in this particular case was not as practical as it was benevolent, in as much as the mass of the individuals at New Harmony were not prepared for so advanced a measure.

In an address at New Harmony Hall on April 13, 1828, Owen said, speaking of the failure of his experiment:

> This proves that families trained in the individual system, have not acquired those moral characteristics of forebearance and charity necessary for confidence and harmony; and communities, to be successful, must consist of persons devoid of prejudice, and possessed of moral feelings in unison with the laws of human nature.[18]

Other observers concluded that a communistic system such as Owen had devised could not exist unless in a place utterly removed from contact with the world or save with the help of some powerful religious conviction.[19]

To the extent in which the institutions of private property, religion, and marriage were eliminated or controlled as constant conditions in the life of New Harmony, we have here a real social experiment. On the assumption that these three fundamental human institutions were actually eliminated or reduced to constant elements, we have experimental proof of the instability of society without them. But granting all this, general conclusions are invalidated by the fact of heterogeneity of population a variable and uncontrolled element in the experiment. The deplorable absence of like-mindedness in New Harmony vitiates any inference as to the ultimate effect upon society of the elimination of these fundamental institutions, unless it be the conclusion that without the unifying discipline of these factors a heterogeneous aggregate of people can not live together in peace and harmony. But this is not a new principle of sociological knowledge.

Charles Fourier (1772–1837), the contemporary of Robert Owen, was also a keen critic of the existing industrial system and placed great stress on the principle of association as a remedy for social injustice. Fourier advocated the reconstruction of society on the lines of small self-supporting cooperative communities called phalanxes. Each association was to be composed of some 1,800 members who worked in harmony with one another for the benefit of the community. Every

[18] Lockwood, *op. cit.*, p. 214.
[19] Hinds, *op. cit.*, p. 135.

worker was to take up a different task at the end of two hours, in order that there might be the spice of variety. Labor was to be paid for in order of the necessity, usefulness and agreeableness of the task. He believed that the proposed reorganization of society would permit all who started productive work at eighteen to retire for a life of leisure at twenty-eight.

Fourier's ideas were accepted with enthusiasm by the inhabitants of Brook Farm in 1844. This interesting community was organized in 1841 by a group of New England idealists—orators, philosophers, poets and transcendentalists. The Rev. George Ripley, founder of the Brook Farm society, proposed "to establish the external relations of life on the basis of wisdom and purity; to apply the principles of justice and love to our social organization in accordance with the laws of Divine Providence; to substitute a system of brotherly cooperation for one of selfish competition; to institute an attractive, efficient and productive system of industry; to diminish the desire of excessive accumulation by making the acquisition of individual property subservient to upright and disinterested uses; and to guarantee to each other forever the means of physical support and spiritual progress."[20]

The association was founded on a joint-stock proprietorship with capital shares of $100 each and a guaranty of five per cent. per annum interest return. Although communism in the basic property of the community was not practised, there were common industries, equal wages, a common guaranty of support to all members, their children and family dependents, and housing, food, clothing, and other necessities without charge exceeding a certain amount fixed annually by the members. Education and the use of the library were free to all members.[21]

> The aim was to secure as many hours as was practicable from the necessary toil of providing for the wants of the body, that there might be more leisure to provide for the deeper wants of the soul.[22]

The testimony of observers seems to be agreed that this association of idealists lived in harmonious relations. It is said that the survivors of Brook Farm long cherished the memory of the few years spent in associative life as the happiest and most profitable they had known.[23]

The acceptance of Fourierism in 1844 appears to have come at a juncture in the history of Brook Farm when financial difficulties made the future existence of the experiment problematical. A new constitution was adopted and the society was incorporated by the state legislature. A rather complicated system of government was drawn up and the industrial organization of the community was worked out with

[20] Preamble to Articles of Agreement and Association, signed by the Brook Farmers.

[21] Hinds, *op. cit.*, pp. 231–232.

[22] Frothingham's account of Brook Farm, quoted by Hinds.

[23] Hinds, *op. cit.*, p. 231.

typical Fourieristic detail—farming series, mechanical series, domestic series, and so on, each series being subdivided into many groups. For a time there appears to have been a profitable renewal of industrial activity, but the financial problem was still unsettled. Finally, a great disaster, the destruction by fire of the large $7,000 unitary building, had such a depressing effect upon the members that one by one they lost heart and departed.[24] The experiment was brought to a close in 1847 after six years of harmonious community life.

In many respects the Brook Farm experiment was a complete contrast to the New Harmony experiment. In the one, harmonious relations were enjoyed for six years by a small group of like-minded and highly cultured people who, however, failed to make their communism a financial success; in the other, friction and lack of harmony existed from the first among the heterogeneous aggregate, and although the financial backing was adequate and generous, the experiment came to a disastrous end in two years. It is difficult to draw any general conclusions from the Brook Farm experiment which will be sufficiently definite to have sociological value. The one outstanding fact, however, seems to be that like-mindedness is sometimes a more fundamental condition of community survival than material endowment. But here again, local experimentation has established no new sociological principle.

The most successful experiment in Fourieristic principles was the North American Phalanx organized August 12, 1843, near Red Bank, Monmouth County, New Jersey, and continuing with considerable prosperity for thirteen years. The New York *Tribune* described the community in 1854 as located on a domain of 673 acres of land, equipped with steam flour and saw-mills, a mansion house, packing house, carpenter's shops and blacksmith's shops. Near the mansion house was a nursery where the children were taken care of while their mothers worked. The inhabitants numbered about one hundred persons. Labor was divided into various departments occupied with fruit drying, the bottling of fruit, the cultivation of potatoes, tomatoes, turnips, melons, cucumbers and garden seeds, the manufacture of wheat, rye, and buckwheat flour, corn meal, samp and hominy. The labor of each person was credited by the hour and charged with board, lodging and other things received from the association. The balance due for excess labor value was paid in cash.

This community weathered many of the preliminary dangers which had broken up other experiments of a similar nature. There were personal difficulties and two parties contended for authority, yet neither of these factors was directly responsible for the final dissolution of the association. As late as August, 1855, a visitor to the phalanx testified

[24] *Ibid.*, pp. 233–239.

to the still prevailing spirit of contentment. Yet shortly after this favorable report a difference of opinion arose concerning the location of a new mill and when the question was put to vote the majority was found to be in favor of dissolving the community.[25]

The causes of the dissolution seem to have been various: among the chief of them was lack of educational facilities, a secession of some of the members, the burning of the mill, and dissatisfaction about the return paid for labor. It appears that there was not sufficient distinction between labor of brain and muscle. The president received only ten cents a day more than a common laborer. It is significant that wage troubles were such an important factor in causing dissatisfaction when it is recalled that the community was established for the very purpose of destroying wealth and income distinctions. Hinds makes this comment upon the fact:

> But all this talk about wage troubles, to my mind, only proves that the great objects which originally drew the members together had lost their first power over them, and that lower and more material considerations were becoming dominant in their minds and hearts.[26]

This community experiment appears to have been well endowed materially and not to have suffered much from internal dissension. What was the cause of its failure? It would seem from the foregoing enumeration of causes that the most potent factor was lack of isolation from the disturbing influences of outside society. It should be remembered that all of these community experiments[27] were carried on in a social medium, and that the guiding motives of life in surrounding society, the prejudices, the customs, the laws, the forces and various principles of elemental human nature, were uneliminated and troublesome influences. Scientific experimentation under such limited conditions of control was impossible. (It was like attempting to conduct a chemical experiment in a bowl of molasses.) Consequently the conclusions from such experiments must be qualified by the unsatisfactory control of the experiment.

The condition of isolation so fundamental for successful social experimentation was never actually realized in the utopian community experiments, and it is an open question whether this prime condition can ever be enforced in social experimentation by active human interference. But sovereign states have, however, experimented upon the people without the aid of this important condition. Since the subject is obviously unlimited from the historical point of view, it will be well to confine our analysis to a few typical contemporary cases.

(To be Continued)

25 Hinds, *op. cit.*, pp. 243, 247.

26 P. 248.

27 There were in all twenty-nine Fourieristic communities in the United States with memberships of from 20 to 420 persons, with lands of from 150 to 30,000 acres, and lasting for from six months to thirteen years each. Hinds, p. 224.

THE LUCK ELEMENT[1]

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THE prime necessity of human life on earth, as of all life, is adaptation to life-conditions. Human beings have found themselves confronted by various sets of these conditions, and have reacted upon them in a characteristic way; but whereas plants and animals have been forced to structural adjustments, on the basis of which they are classified into varieties, species and genera, men have performed mental and social adaptations, nearly as automatic at first as those of other organic beings, on the basis of which they are classified into grades of civilization. These life-conditions include those of the natural environment, such as climate, flora and fauna; those of the social environment of fellow-men; and those of the environment of ghosts and spirits. Adjustment to these several sets of conditions is through common modes of conduct, or folkways, out of which gradually crystallize the institutions of society.

A condition of a less material order which the most primitive of men were obliged to recognize as a part of life on earth, and to which they had to adapt themselves, was what we call chance or luck. Efforts and results are found not to be strictly in proportion, though experience shows a correlation between them upon which the race, in actual living, has had to depend. The same effort in hunting, put forth upon two separate occasions, has resulted now in plenty, easily obtained, and again in destitution and fatigue. Variation from the expected is always taking place, in all ages and stages. The liner strikes the derelict, drifting awash; the tire picks up a nail; the ivories kiss just as a hard shot and an excellent position are about to be attained; the baseball strikes an uneven spot and jumps over the fielder's head—and disappointed men groan over "bad luck" and "jinxes." The liner shaves the derelict; the nail is found to have little more than scratched the tire; a kiss results in making a shot and attaining a position uncontemplated; the safe hit is deflected into the fielder's hands—and then the favored men exult over "good luck" and "horse-shoes."

[1] This conception of the luck element in its relation to the evolution of religious beliefs and practises is based upon an analysis developed, mainly in lectures, by Professor Sumner. It has seemed to many of us both profound and suggestive, and we think it should be more widely known, and known as his. It is somewhat elaborated here; but the basic idea is not the writer's.

Luck plays a great part in any one's life. It may make or ruin. Upon the primitive stage it is the more significant because men live, so to speak, on the edge of existence, and it does not take much mischance to push them over. What wonder, therefore, that this element in life has occupied men's thoughts through the ages? They have loved it and feared it; and they have played with it as with no other interest. "Interest" is the word for their attitude toward it. The passion for getting something for nothing and the fear of getting nothing for something have always fascinated the human mind.

It would be entirely irregular if the presence of an element like this, among the life-conditions, had not evoked, in the course of social evolution, an important set of social adaptations. Reaction upon the physical environment has resulted in the industrial organization of society. Relations with the social environment have worked out into domestic and political institutions. The biological fact that *homo* is bisexual has led to a long series of adaptations that would not have appeared had *homo* been an unisexual organism. What human institutions correspond to the presence in the field of the element of chance or luck?

But, first, let us examine the element itself. Modern science, of course, recognizes no such thing as chance, in the sense of a result without a sufficient cause. It believes that nothing ever "just happened." The most "fortuitous" event can be explained if there is knowledge enough. The liner reached a certain point of latitude and longitude, at a certain instant, as the result of numerous contributing causes—steam-pressure, head-winds, gales, strikes, temperament of captain, and so on—the action of any one of which could have been predicted if knowledge had been sufficient. Similarly with the derelict. The collision was, therefore, in the natural order of things. There was no miracle or magic about it. The nail lay in such a position that it was bound to make a puncture or merely to scratch the tire. The billiard-balls were sure to kiss at the exact spot where they did kiss, being struck as they were. The inequality in the ground being such as it was, and the baseball coming as it did, the result could be indefinitely repeated if the conditions could be duplicated. It is all a question of knowing and foreseeing. To omniscience there could be no "luck"; to advancing knowledge there is less luck; and, as one set of phenomena after another is included within the range of rational explanation, the conviction has grown that law obtains throughout the universe, to the total exclusion of chance.

Luck, then, is a name for that which is inexplicable on our stage of knowledge, or in view of our unwillingness to take the trouble to get or apply that knowledge. It is what we are too ignorant or too unenterprising to figure out. Omitting the latter consideration as representing the entrance of the personal equation, the importance assigned to

luck varies inversely with the amount of knowledge. This means, however, since the knowable is immeasurably vast, that the luck element will always be an immense factor in human destiny.

Perhaps it is superfluous to point out that we currently recognize this relation of chance and knowledge. If a man "takes no chance" it means that he is informing himself to the utmost—indeed, he may even be fully informed and "betting on a sure thing." And after listening awhile to a person whining over his bad luck, are we not often exasperated into a partial personal investigation of his case, with the result that we find "not so much bad luck as bad management"? Again, when the small boy lays his finger upon the hot stove, we comfort him and say "Hard luck, old chap!" It was that, to him—he "didn't know any better." And, in our condolence, we put ourselves in his place. If a grown man should do the same thing and howl over his experience, the answer might be: "Serves you right! You knew better than to do that—or, anyhow, you ought to have known better."

Now the savage is like the child. His knowledge, beyond the restricted sphere of immediate experience, is small. The explicable, to him, is an exceedingly limited range; and the range of the inexplicable, the unreckonable, is correspondingly wide. Add to this the fact that ill luck, even a little of it, is a vastly more serious matter to him than to civilized man, and the significance to his destiny of the luck element—the "aleatory element" of Professor Sumner—is indefinitely enhanced. It forms for him, as the facts show, one of the major conditions of life on earth; and his adaptation to it, as he sees it, works out into an important set of social structures.

Nowadays civilized man has at hand an adaptation to the aleatory element which is the fine fruit of some of primitive man's primeval gropings toward safety in the face of mischance, viz., insurance. Insurance, in itself, does not lessen the losses involved, but it distributes them so they can more easily be borne. It reduces a variable of shattering loss to a constant of endurable loss. It is always loss, be it noted—loss, submitted to in order to avoid utter calamity. In insurance-operations recourse is had to the laws of chance and actuaries figure out about what amount of mischance can be reckoned on. Then this is distributed in the form of premiums paid on policies. Insurance is a grand device, and its roots go farther back than one would think, offhand. Mankind on earth has always had an eye to the avoidance of ill luck, and in all ages has tried somehow to insure himself—to take out a "policy" of some sort. His methods of so doing were often rude and mistaken, but they were susceptible of replacement and rectification. Only by some such device was existence possible, in the presence of the menacing inexplicable.

But it may be objected that there is just as much good luck as ill luck, and the optimist will doubtless remark that all is for the best in this best of worlds. There is room for a difference of opinion here, no doubt; but the fact is that the tendency of human nature is to take good luck to be normal and as the matter of course, and to confine attention pretty largely to the ill fortune. Perfect health is not normal, yet we go on the theory that it is, and grumble at illness as a misfortune. Age brings on a series of discomforts; they are perfectly normal; but we still refuse to consider the good days as good fortune, and complain about the bad ones. That man was a great philosopher who kept a diary to which he looked back at times of discomfort, always finding some occasion when he was worse off. We do not take much pleasure in past joys when we are being plagued, but subscribe rather to the sentiment about sorrow's crown of sorrows being the remembrance of happier things.

But engrossment in the present is the rule among peoples whose representative faculties are relatively weak. Also, among the primitive folk, as has been intimated, ill luck is more important than good luck because, while the latter may be highly desirable, the former is supremely undesirable. It may mean present death; or a disablement, readily curable by us, but permanent and in the highest degree dangerous on a low stage of civilization; or some hideous disease. The experience of good luck never relieves people on that stage of the present fear of ill—indeed, a run of good fortune frightens them to the last degree, for it is a sure harbinger of calamity. Witness Polycrates. It is necessary to walk very softly when things go well, with an eye always cocked toward the perennial menace of ill. And if we recall the manifold dangers surrounding human life, before the barrier of civilization was built up to afford it some protection, we shall not be surprised at the prevalence of interest in avoiding ill as over against interest in attaining good. It is necessary to set ourselves in the situation of primitive man to realize this; but any one can help himself to do that if he will realize that the savage was really involved in a struggle for existence, whereas none of us are. We struggle for a standard of living; and if we lose out utterly, still existence is assured to us by the society in which we live. But our far-away ancestors, and their present-day representatives, the nature-peoples, lived and live in a direct relation to physical environment, one full of perils of a vital order. They were and are victims of a vivid fear of calamity; the "free and noble savage" was a philosopher's phantasm.

With the aleatory element, especially in its negative phase of ill fortune, filling the perspective as an enduring and real menace—forming one of the major conditions of life—the primitive man at once sensed the discomfort that enforces adaptation. His attitude could

not be one of indifference, nor could his mind develop or harbor the more evolved conceptions that characterize a higher civilization. He could not conceive of the refined faith of the civilized man, any more than of the resignation of the stoic or the more enlightened resignation of the agnostic. Yet he must do something to avoid ill; and for that he must have some explanation of the inexplicable. It was not that he was at all the victim of intellectual curiosity. If this matter had not touched vitally upon his most vital interests, he would never have sensed the need of explanations. There had to be something accounting for the aleatory element, precisely in order to deal with it. He was not after any pure science at all, but the question was simply: What to do? How to insure against ill, that always threatened, but was not to be accounted for upon any basis of actual experience?

This was the issue that lay before the primitive folk in the face of this peculiar and inevitable life-condition. If anybody imagines that they attacked the issue and solved it by a conscious rational procedure, he has yet a great deal to learn about the early stages of society's evolution. Primitive people could not even have formulated the issue, let alone applying ratiocination to it. They felt it in a dull sort of way, and squirmed and fumbled about to dodge the pain or secure some alleviation. How, automatically and un-rationally, to get hold of some explanation of the inexplicable—that seems to be a problem indeed for childlike minds with but slight and unreliable equipment of matter and method.

In the primitive mental outfit, however, there existed a set of beliefs competent to account for all mysteries. Starting with a belief in the double or soul, practically all primitive people have developed the notion of the ghost and spirit, an evolution expounded by Spencer and others. And in this animism and daimonism there existed an entirely sufficient explanation of any and all the phenomena of the aleatory element. I do not need to go into the details of this matter. It is enough to say that the daimons were all-powerful, irresistible by unaided man, capable of inflicting "strange agonies" of all sorts, and, for the most part (corresponding to the aforesaid preoccupation with the negative side of the luck-element) they were maleficent. Whether ill-intentioned or not, their presence was productive of ill; the ghost of a dead mother, embracing her child, would cause its death or otherwise afflict it. There was, in short, no woe or calamity of man that could not be referred to the spirits. The spirit environment formed a complete and ready explanation for any and every phase of the aleatory element.

It is not asserted that the recognition, conscious or unconscious, of the element of chance summoned into being the idea of the spirit environment. That conception arose from other sources altogether.

But it was there, and it explained the otherwise inexplicable. The two conceptions dovetailed together, and out of this situation arose that important complex of social institutions of primitive times which we know as primitive religion.

The two conceptions still cling together. Inexplicable or unforeseeable calamities are still designated, generalizing, as "acts of God" or "acts of Providence." What men can understand and provide against they do not so designate. The range of the aleatory element has been much restricted by the growth of knowledge—we do not need the supernatural explanation of fossils, or thunder, or the plague any more, but explain by "lower" causes where they can be enlisted.

However the range of the aleatory element, as the inexplicable, is and always has been infinite; and so the inroads of knowledge and science amount in the end to subtracting something from infinity. The remainder is still infinity. But it satisfies the mind and clarifies the course of social evolution to note this one among the several cases of adaptation to life-conditions exhibited by the race. If there had been no luck element, there might have been a very different sort of animism, daimonism, and religion. As it actually has been, the former was a condition of life on earth to which men automatically adjusted themselves by recourse to the development of the religious institutions.

MENTAL AND MUSCULAR WORK

By Dr. JAMES FREDERICK ROGERS

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THOSE who have had the opportunity of observing the results of muscular and mental effort have often noted a coincidence between the ability of a pupil to perform gymnastic feats and his proficiency in theoretical studies; and the generalization has been made that there is an intimate relationship between muscular and mental power. For a study of this relationship the power of grip ("strength of forearm" as it has been called) as recorded by the spring dynamometer, of seventy-five young women of one class of the New Haven Normal School of Gymnastics, was compared with the marks received (average of two examinations) in the study of human anatomy. The slight similarity between the results of these tests for muscular and mental effort was so apparent, when the marks were down on paper, that a comparison by groups alone seemed worth while. The grouping was made according as the pupils received a mark of 90 or more, 80 to 89, 70 to 79, and 69 or less in anatomy, the largest number of the class (thirty-eight) falling into the third group.

The average of the strength tests for each group was: for the 90 or more, 37 kg.; for the 80 to 89, 35 kg.; for the 70 to 79, 31 kg.; and for those below 70, 35.5 kg. The lowest strength record, 22 kg., was made by a pupil who received an anatomy mark of 75. The greatest display of strength, 49 kg., was exhibited by two members of the class, one of whom received an examination mark of 91 and the other 80. One of these with an anatomy mark of over 90 gave a strength test of only 30. The lowest strength test given by those who attained over 90 was 30 kg., and the same grip was the lowest exerted by those who did not reach above 69.

From such figures and such means of comparison, there is (on the strength plane represented by a grip of 22 kg. or more) evidently very slight connection between the results of mental and muscular effort. However, the markings for anatomy represent prolonged mental effort, while the display of muscular force upon a dynamometer does not indicate the possible power for continued muscular exertion. There might be a closer relationship between mental marks and tests for prolonged muscular work. As a simple measure of the endurance of the pupils they were asked to hold one arm in the abducted horizontal position as long as possible. The variation in the results of this test was far wider than that for the brief display of muscular force, and there was little correspondence between the strength and endurance tests of each indi-

vidual. One young lady who gripped with a force of 49 kg. held her arm out for only three minutes and 45 seconds, while another, whose grip was but 22, kept her arm raised for seventeen minutes.

Individually again there was no relation between muscular and mental endurance, if we can so speak, only one of those receiving a mark of over 90 showing muscular endurance of more than 10 minutes, while one who received 66 held her arm out for 95 minutes, and one who had a mark of 70 made an unfinished record of 121 minutes.

The wide variation in the powers of endurance as shown by this test are of much physiologic interest. Two of the tests were incomplete, owing to lack of time. One of these young women felt no fatigue at the end of an hour, nor the other at the end of two hours. A similar wide variation was shown in the tests made by Prof. Irving Fisher,[1] in which both arms were held horizontally, from a minimum of six to a maximum of two hundred minutes. In the latter tests, flesh-eaters attained an average record of only twenty-two minutes and there seemed to be some proof that the vegetarians in the contest had superior powers of endurance. All members of the group tested in the normal school were flesh-eaters, most of them ate at the same table, and all had received for months the same muscular training. These endurance tests were taken without class competition.

In addition to the above tests and comparison, a similar endurance test was taken of eighty-six freshmen boys in the high school, near the end of the school year. A rough average of the marks for the year in all mental branches was made, using the system of grading of the school. Those having an average of over 90 falling in grade A, between 75 and 90 in grade B, between 60 and 75 in grade C. The endurance test was taken in class and was limited to twenty minutes. While many would have held out longer, the general result would probably have been much the same, for the Class A pupils gave an average of 12⅓ minutes, the Class B 16 minutes plus, and Class C 13.9 minutes. The high-school boys did not therefore exhibit any more connection between mental and muscular powers than did the normal-school girls. Not even does the superior ambition which is presumed to impel to mental superiority seem to have any effect in adding to the prolongation of neuro-muscular effort of those of high scholarship.

From the results of such uncertain means of measurement the variability in powers of muscular exertion and especially of prolonged muscular work, are evidently as great as for mental effort, or, more accurately stated, the neuro-muscular quality of prolonged effort is as variable as the cerebral qualities involved in acquiring and expressing an orderly collection of facts on a given subject. The wideness in variation of the neuro-muscular quality among those who have for a

1 "The Influence of Flesh-Eating on Endurance," Irving Fisher, Ph.D., *Yale Medical Journal*, March, 1907.

considerable time been subject to the same diet and the same gymnastic and athletic exercises shows that the quality is innate and subject to little modification by training. A like inherent power for grasping a subject must have been noted by all teachers of mental work and the discouragingly slight change in quality of such work brought about by the efforts of the teacher is also familiar.

While such a comparison of tests would seem to show that there is little connection between exercise of the mind in school work and the exercise of the muscles in strength and endurance tests, it does not follow that the results of mental work carried on through one's own initiative may not correspond more nearly with one's power of muscular endurance, nor does it signify that mental superiority, and that complex which we call health, have no intimate connection. As Emerson said, "For performance of great work it needs extraordinary health." "When nature goes to create a great man she puts a symmetry between the physical and intellectual powers." The man of genius certainly has, as a rule, been a man of most unusual bodily powers. Napoleon, up to the time he became emperor, knew no such thing as fatigue. He said of himself that he had "the constitution of an ox." Tolstoi, at the age of fifty-eight, walked 130 miles in three days without fatigue. Porson, the great Greek scholar, frequently walked 52 miles to his club. Walter Scott was a supremely healthy man who could walk thirty miles a day. Samuel Johnson, Goethe, Humboldt, Wordsworth, Tennyson, Browning, Brahms, Beethoven, Wesley, Beecher, Gibbon, Washington, Lincoln, are but a few examples of men of genius who showed great bodily powers. There are exceptions to the rule, though these were none the greater for being exceptional. Even geniuses of slight physique, such as DeQuincy and Charles Lamb, were tireless walkers, Poe was athletic before he was overcome by alcohol, and even Stevenson showed unusual muscular powers for so sickly a person. Doubtless walking would be a far better test of endurance than the mere extending of the arms. As for strength tests, we know that Franklin astonished his printer companions by carrying two forms of type to their one; that Tolstoi could lift a hundred and eighty pounds with one hand, and that Walter Scott as a young man "could lift a smith's anvil with one hand, by what is called the horn." Scott does not give the weight of the anvil, but the feat was evidently an extraordinary one. Lincoln, it is said, could lift three times as heavy a weight as any common man. None of these men (unless it was Tolstoi) underwent any systematic "physical training" and the muscular powers they exhibited were either inborn, or developed along with the extraordinary exercise of their mental machinery. We do not know what relationship the ideational bear to the motor regions of the brain, but the exercise of the former must bring to the latter a blood supply which they would not otherwise receive, and these batteries, from which muscular activities are originated, might be the larger and more powerful for such association.

Though the foregoing figures do not prove, they do not disprove that the combination of a superior showing in muscular strength or endurance with superior showing in mental effort makes (other things being equal) for the best prospect for future accomplishment. Chief among the "other things" are ambition and the incentive of material needs. Poverty, or the fear of poverty, is a better soil for genius than prosperous surroundings. Much of the world's choicest production, in art or literature, would never have existed had bread and butter been forthcoming without work.

The results of these tests are of more use in what they do not prove than in what they prove. They are suggestive especially of the complexity of the matter examined and the questionableness of the value of such tests of either muscular or mental effort. The successful application of the mental machinery to routine school work depends upon heredity and extra-educational conditions, the brain being, with the same perfection of bodily backing, easily set to work upon scholarly pursuits in the one case, while in another case these are as foreign as the weaving of silk to a threshing machine. The man of genius toils joyously where the average student works without interest as well as without fitness for his task. Even the man of genius, as Boileau, Rousseau or Goldsmith, has sometimes seemed a dunce in his work at school.

The great variation in the results of these tests of strength and endurance emphasizes the fact (well enough known but often overlooked) that these, like mental qualities, are inborn, are not to be created by any form of training, and that, given the opportunity, they will develop to near their maximum. Muscular or mental training furnishes only an aid to completest development and maintenance of these powers. In systematic gymnastic, manual, and other forms of physical training there is combined training of both muscular and mental faculty. Unless muscular exercise is overdone it helps to maintain health and so to keep the mental powers at their best. A DeQuincy may feel the need of a walk of at least fourteen miles a day. An Edwin Booth or a Lord Lyons may find himself as well off with a minimum of muscular effort. The remark of Emerson, after his experience in gardening for health (into which he was inveigled by the enthusiastic counsel of Thoreau), is significant. He wrote:

> If I judge from my own experience I should unsay all my fine things, I fear, concerning the manual labor of literary men. . . . To be sure he may work in the garden, but his stay there must be measured, not by the needs of the garden, but of the study.
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> When the terrestrial corn, beets, onions and tomatoes flourish, the celestial archetypes do not.[2]

[2] The writer is much indebted to Miss Nina A. Dudley, of the New Haven Normal School of Gymnastics, and to Mr. Rufus A. Spencer, of the New Haven High School, for directing the tests here described.

MILK, SANITARY AND OTHERWISE

By Dr. JOHN WADDELL

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SEEING that for a length of time, extending from a number of days to a year or more, milk is the sole food of over two thousand species of animals among which are the mouse and the elephant, the porpoise and the whale, and also the bat and the flying squirrel, it is evident that it must play a very important part in the economy of nature.

Milk is sometimes called a perfect food and the milk of each species may be considered such for the young of the same species. It contains all the essentials of a food, namely, carbohydrates, fats, protein and mineral salts. Carbohydrates form a group of organic compounds, which include sugar, starch and cellulose, and are composed of carbon, of which the most common form is charcoal and of hydrogen and oxygen in the proportion in which they exist in water. Fats are also compounds of carbon, hydrogen and oxygen, but in different proportions and in a different state of combination from those found in the carbohydrates. The carbohydrates and fats burn in the body as wood or coal burns in a furnace. They are capable of supplying the heat of the body and the energy that is required for its activity but they can not build up new tissue nor repair waste. This is the function of protein, so called from the many forms in which it exists. The name is a general one for a number of more or less distinct substances which agree in having a complicated structure in which nitrogen is an essential element and in which sulphur and phosphorus frequently occur. Muscular fiber consists largely of protein, and as protein is the part of the food which supports growth it is absolutely necessary. If more protein is taken into the system than is necessary for the nutrition of the tissues, it may supply energy and heat, but, for the same amount of heating value, proteins are much more expensive than carbohydrates. Excess of protein, as well as excess of fats or carbohydrates, may be used to increase the fat of the body. Animals are fattened by heavy feeding in many cases. Protein is formed in lean meat and in the white of egg and is the essential though not the largest part of cheese.

The carbohydrate in milk is chiefly milk sugar, which is in many respects similar to cane sugar, but is not quite so sweet and is not fermentable by ordinary yeast to form alcohol.

The fat does not differ more from other fats than they do among

themselves, but it contains a small quantity of compounds which on decomposition give butyric and other acids, causing rancidity.

The proteins in milk are of two kinds, casein and albumin, and the milk of different species of animals differs more in the character of the proteins than of the other substances. Casein coagulates in the stomach by the action of rennin, albumin does not coagulate in this way. The relative quantities of these differ in different kinds of milk and the nearest to human milk in the character of the protein and indeed in all respects except the percentage of fat is that of asses. The milk of reindeer contains a large amount of fat, almost as much as the cream of ordinary cow's milk and it also contains a large amount of casein.

Though we are accustomed in this country to use only cow's milk, the milk of other animals, as is well known, is used in other lands. In Scandinavia and other northern regions reindeer's milk is a common article of diet, its fat content making it specially valuable there. Camel's milk is in favor in desert countries, mare's milk in Russia and Central Asia, while goat's milk is not only common in the hilly countries of Europe, but is sold on the streets of Paris. One of the picturesque sights of that city is a goatherd leading his flock through the streets and stopping to milk as from time to time a customer appears. In the Marais, a district not far from the Louvre, formerly an aristocratic quarter, but now a congested area of slums, a goatherd may frequently be seen sitting on the step of a door surmounted by the armorial bearings of some scion of the nobility, drawing from a goat the quarter litre of milk demanded by a ragged woman for her squalid child. Nor is goat's milk used in the poor quarters alone. Near the Bois de Boulogne, in the early morning hours one may be wakened by the sweet notes of the shepherd's pipe and may, if quick enough, catch sight of him as he jauntily leads his herd along for the benefit of this district also.

While the casein in milk is coagulated upon entrance into the stomach, that of different animals coagulates in different ways. One typical method is that of the cow, sheep, or goat, examples of ruminant animals. In these animals the casein coagulates to a solid mass, which remains for a considerable time in the stomach and is there largely digested. This prepares the stomach for the later digestion of hay and other material of a similar nature. The second typical method of coagulation is that found in the milk of the mare or ass, non-ruminant animals, whose digestion is mainly intestinal. This coagulation is gelatinous, and the material passes rapidly from the stomach to the intestines. The third form of coagulation is intermediate; flocculent masses being produced which though digested to a greater extent in the stomach than in the second case are not nearly so fully digested as in the first case. An example of this kind of flocculent coagulation is

afforded by human milk, which in this respect also more resembles that of the ass than that of the cow.

When we speak of milk without any specification we always mean cow's milk and it may be well to make a comparison between the average cow's milk and the average human milk. Of course, the great bulk is water, being a fraction over 87 per cent. in each case. In human milk the total solids are 12.6 per cent. and in cow's milk 12.8 per cent. In human milk the total protein is 2 per cent., two fifths being casein and three fifths albumin; cow's milk contains about 3.4 per cent of protein, more than five sixths of which is casein. The fats are practically the same in both kinds of milk, being 3.7 per cent. Human milk has a greater percentage of milk sugar, namely, 6.4, while cow's milk has nearly 5 per cent. The mineral matters in cow's milk are 0.7 per cent., and in human milk 0.3 per cent.

The figures given are of course an approximate average. Different breeds of cows not only give different quantities of milk, but different percentage composition as well. It may be remarked that farmers should keep an individual record of each cow so that they may know how much milk each produces, and at what cost. It is considered by good judges that one quarter of the cows kept for dairy purposes do not pay for their keep, and that nearly another quarter yield no profit, leaving only one half to bring in money. Ayrshires, Jerseys and Guernseys may be expected to give about 6,000 pounds of milk in a year, while Holstein-Friesians may be expected to give 7,500–8,000 pounds. Individual Ayrshires and Guernseys have given over 12,000 pounds, nearly 17,000 pounds have been given by Jerseys, and Holstein-Friesians have frequently been known to give 20,000–30,000 pounds. The milk of the Holstein-Friesians is usually thin, low in total solids and lacking in fat. While the average fat for Ayrshires may be taken as about 3.6 per cent. and for Guernseys and Jerseys about 5.2 per cent., that of Holsteins is about 3.4 per cent.

The fat in milk is in very fine globules and forms an emulsion. Being lighter than the rest of the milk, it is separated by its specific gravity either by rising to the top on standing or by means of a separator. It is because of its finely divided condition that cream is more easily digested than other fats. In the case of Guernsey and Jersey cows the globules are larger than in other breeds and their milk is sometimes not considered so suitable for invalids.

Milk may be deprived of part of its water, thus making it more easily transported. The term "condensed milk" is applied to milk that has been partially evaporated and to which sugar has been added. "Plain condensed milk" means milk concentrated without addition of sugar and it is commonly sold in bulk. "Evaporated milk" is normal milk reduced to about half its original volume. It is similar in keeping

power to pasteurized milk and is chiefly used by confectioners and ice-cream manufacturers. Condensed milk if obtained from whole milk has about one third the original volume, if from skim milk one fourth. The condensation is usually effected in vacuum pans, by which means the water evaporates at a comparatively low temperature, thus changing the character of the contents but slightly. In 1912 the condensed milk factories in the United States had a capacity of about 15,000,000 pounds a day, the product probably of a million cows, though under proper conditions a million cows should yield a greater amount of milk.

A further step in the removal of water produces desiccated milk. The process, however, is quite different, for, in order to prevent change in the character of the solids, the evaporation must be very rapid. The milk is dried at a temperature of about 220–230° F. in about thirty seconds. When the milk powder is mixed with water in the proper proportions milk similar to the original is obtained. Approximately 90 per cent. of the desiccated milk manufactured is made from skim milk; the fat of whole milk is liable to become rancid on long keeping. Desiccated milk is completely free from bacteria; germs can not develop in it. The process is in use in many of the best dairies in Europe, also in Australia and the Argentine Republic.

A number of years ago an experiment was made in New York with 850 babies ranging from five days to a year old. Sugar of milk was added to the dried milk which was sometimes whole milk and sometimes different mixtures of milk and cream. This was fed during the four hottest months of the year. The mothers were instructed how to mix the powder with water and were told not to keep the milk any length of time after it was made up but to throw away whatever was left by the infant. Not a single child died. It was found that this milk did not clot in the stomach like ordinary milk, but in granular clots like human milk.

A very important characteristic of milk is that it is peculiarly adapted to the growth of lower organisms among which bacteria of various kinds are prominent. It is a food for them as it is a food for higher organisms. The souring of milk is brought about by bacteria which change milk sugar into lactic acid. These bacteria do not propagate by spores, and as it is spores that can stand the greatest variations of temperature the lactic acid bacteria are destroyed at a temperature not very high. Lactic acid bacteria are widespread, and it is almost impossible to get milk that does not contain them. As the milk sours the casein combines with the acid, forming a curd. When the milk begins to taste sour the growth of nearly all non-acid-forming bacteria is checked and in distinctly sour milk the bacteria are usually confined to two or three closely related varieties. Lactic acid bacteria are con-

sidered very beneficial in butter and cheese making, though usually thought to be objectionable in milk.

Besides the sour curdling of milk there is a sweet curdling similar to what takes place in the stomach when milk is drunk. The rennet of calves is used for the purpose. It contains what is technically called an enzyme. The curd is changed afterwards into a soluble material by another enzyme, pepsin. These are bacteria that produce similar enzymes and so a curd may be digested, as it were, by these bacteria. Sometimes the weather may be so hot as to be more suitable for these bacteria than for those producing lactic acid, and very little curd may be formed.

While speaking of casein it may be well to mention that when casein is subjected to great pressure it is converted into a ductile substance called lactite, which may be used instead of celluloid as an imitation ivory, for napkin rings, combs, handles of knives and walking sticks and for the veneering of furniture.

The typical lactic acid bacteria have, so far as known, no poisonous products and sour milk is probably valuable in many diseases, especially those which arise from putrefying bacteria in the intestines. Other bacteria which produce a ropy condition of the milk are also not considered harmful, but to most people ropy milk is disagreeable. The ropiness is due not to the curdling of casein, but to the bacteria themselves, which are held together by a slimy substance secreted by them. Koumiss, originally made from mare's milk, combines an alcoholic fermentation with that of lactic acid. The alcoholic fermentation is brought about in milk sugar not by the ordinary yeast used in making bread, but by a special variety.

Of course, the most important bacteria from the point of view of the consumer are the disease-producing ones. Epidemics of diphtheria and scarlet fever have been traced to milk, also typhoid fever and other diseases. It has been matter of debate whether tuberculosis is transmitted from animals to man, but the balance of expert opinion favors the view that it is. Tuberculosis is very prevalent among cows. In a test made at Washington on 1,538 cows belonging to 104 herds supplying milk to that city it was found that 16.9 per cent. had tuberculosis and this was considered to be below the average, which was estimated to be about 25 per cent. It is not uncommon to find 70–80 per cent. of a herd diseased.

Disease-producing bacteria are seldom isolated from or counted in milk. The total number of bacteria is counted and the count is usually merely an indication of how carefully the milk has been collected or the temperature at which it has been kept. If cleanliness has not been observed at all stages or if the temperature has not been kept down to about 50° F. or lower the bacteria are certain to number many thou-

sands and perhaps millions in a cubic centimeter. Hence for good milk it is important that the cows should be healthy and that the stables should be kept clean. The floors should be made of cement or some non-porous material so that animal waste may be easily removed; the walls should be smooth and without ledges where dust may gather and should be easily washed. Special pains should be taken with the ventilation, the air space for each cow should be at least 600 cubic feet, and there should be large window space, affording abundant light, since light is one of the best germicides. Moreover the cows themselves should be kept clean. They should be carefully groomed and even washed. The grooming should take place some time before the milking so that dust and hairs may not be floating in the air. It is an advantage if a building separate from the stable is used for the milking and that only.

The milker's clothes should be scrupulously clean; a white suit similar to that used by surgeons during an operation is to be recommended. The milk should be caught in a narrow-mouthed pail so as to admit as little dust as possible. The milker should not pass from one cow to another without washing his hands and the milk should be immediately taken to the milk house, where it should be cooled at once. Naturally the milk house must be clean; and all the vessels used should be sterilized by being kept for two minutes in boiling water or, still better, live steam. It is evident that the milk house must be abundantly supplied with hot and cold water.

No matter how carefully and cleanly the milk is produced, if during transportation and delivery it is open to contamination, the consumer is little benefited by the care exercised during the early operations. As soon, then, as the milk is cooled it should be placed in perfectly clean bottles and covered. The paper covers that are often supplied are better than nothing if they are reasonably clean but they are far from ideal. They are difficult to make and to keep sterile. In the "Uviol" method of bottling, tops are made of tin foil coated on the lower side with a germ-free stiffening material and kept in a germ-free package till required for use; and they are put on the bottle by machinery without being touched by the hands during any part of the operation.

The consumer must also observe care in the treatment of milk after it has been delivered. If there is disease in the house, special care is necessary; but many bacteria besides those of contagious diseases are detrimental to milk, some of them causing digestive disorders which in the case of babies may prove fatal. The vessels used for milk should be perfectly clean and the milk should not be exposed to flies and, as little as possible, to the air; and it should be kept cold. Flies are known to have caused typhoid fever; 100,000 *fecal* bacteria have been found on a single fly; while in a particular experiment in which 414

flies were examined there was an average of a million and a quarter bacteria of all kinds on each fly; and flies are common carriers of those bacteria that derange the intestinal system. Vessels used for milk should not be washed with the ordinary dish water but with fresh water. They should not be dried with a towel but should be rinsed with scalding water or still better boiled in water and set away unwiped but turned so that the water may drain out.

The growth of bacteria is inhibited either by low temperature or by high. While at 50° F. the bacteria increase about fourfold in twenty-four hours, and sixfold in forty-eight hours; at about 70° F., they multiply more than 6,000 times in twenty-four hours and nearly 400,000 times in forty-eight hours. These numbers are only typical of the order of growth which varies with different kinds of bacteria, but they illustrate the fact that it is very advisable to keep the temperature down to 50° F. or even better to 40° F.

On the other hand, a sufficiently high temperature destroys microbic growth. This temperature is above the boiling point of water and must be applied under pressure. Such a process is called sterilization. But this high temperature changes the character of the milk, and the growth of bacteria can be much lessened at a lower temperature by the operation called pasteurization. Two processes of pasteurization have been adopted; in the "flash" method the milk is exposed to a temperature of 160° F. for thirty seconds, in the "holder" method it is maintained at a temperature between 140° and 150° F. for thirty minutes. This last method may be carried out in the containing bottles if desired. At 145° F. all of the *disease* germs are destroyed and the majority of the others as well. At this temperature with long exposure a greater number of the putrefying germs in proportion to the souring germs are destroyed than by short exposure at a higher temperature, and as the putrefying germs are the most detrimental, the longer process is the better. Pasteurization does not prevent future growth of bacteria, which propagate with rapidity at blood heat. So after pasteurization the milk should be cooled immediately to a low temperature and kept at a low temperature till required for use. Sometimes thermos bottles are employed for keeping warm, through the night or during a journey, milk intended for babies. If the temperature is sufficiently high, say 145° F., most bacteria do not develop, but on the other hand some whose action is unknown grow in large quantities and if the temperature should fall to 100°–110° F. many bacteria develop so rapidly that in three or four hours the milk is quite unfit for infant's food. Thermos bottles may be used for keeping milk on a journey; but only for keeping it cold. If placed in a thermos bottle at about freezing temperature it will probably keep cool for a long time.

Eighty-eight per cent. of the milk supplied to New York is pasteurized, and 80 per cent. of that supplied to Boston.

In view of the importance of having milk that can be depended upon, medical milk commissions have been established, of which there are less than a hundred in the United States; in Canada there are only two or three. These commissions provide inspectors who frequently examine the herds to see that there are no diseased cows and that the employees are healthy, that the stables and other premises are clean, that the milk is properly treated and cared for during transportation and that it is delivered as soon as possible, thirty hours being the outside limit.

The milk itself is analyzed, the solid contents must be within certain limits and the number of bacteria must be low. Score cards are kept in which certain values are assigned to each feature and in order to be certified the milk must total a certain percentage. The lowest score of a certified dairy of which in 1913 there was any record in the U. S. Bureau of Animal Industry at Washington was 73.6 per cent. and the average of thirty-seven certified milk farms was 90 per cent. At the same time 953 dairies supplying milk in the ordinary way were scored and the average was 41.6 per cent.

About one half of one per cent. of the milk supplied in the United States is certified. The cost is approximately double that of ordinary milk, a matter of consideration to the general consumer but of practically no importance where the health or indeed the life of an infant may be concerned. It should be noted that certified milk is not pasteurized, but is cooled immediately after milking.

It is naturally where milk is to be used by infants that the greatest care is necessary. Every effort should be taken to make the replacement, where necessary, of mother's milk by cow's milk as little injurious as possible.

At Berlin, in 1885, when doubtless hygienic considerations were less attended to than now, the mortality among infants under a year old was that given by the following table:

Infants Fed by	Death Rate per 1,000
Mother's milk	7.6
Nurse's milk	7.4
Animal and human milk	23.6
Animal milk alone	45.6
Animal milk and milk substitute	74.8

So in children's hospitals, children are fed with milk made as nearly like human milk as may be, and every pains is taken that it shall be thoroughly hygienic.

Several years ago Dr. Ralph Vincent, senior physician to the In-

fant's Hospital, Westminster, wrote an article in *Science Progress* upon the milk supplied in that hospital. He pointed out that while well-nurtured children easily get over infectious diseases, badly-nurtured ones recover with difficulty and that complications usually arise. He discussed the contaminated character of the milk supply, especially among the poor of large cities, explained that contaminated milk when boiled is still contaminated and asserted that among the poor the boiling of milk plays an important part in the production of the most fatal disease of infancy, zymotic enteritis, which is largely caused by the putrefactive decomposition of boiled milk.

The milk used at the hospital is very similar to that demanded of certified milk by the medical milk commissions, but in some respects special precautions are taken. There is a rigorous supervision of the diet of the cows. No oil cake nor brewers' grain nor distillery grain is allowed, but grass, hay, pea and bean meal, and mangolds are the chief food. Jersey and Guernsey cows are not admitted to the herd, since the large fat globules are considered too indigestible for invalid children. The milk is delivered within four hours after milking.

Cow's milk has less milk sugar and more casein than human milk. When casein is separated from milk by means of rennet the whey contains the albumin as well as the milk sugar or lactose. The fat content in human milk and cow's milk is the same, so dilution of the milk by addition of whey would make the fat content too low. It is found best to separate the fat from the milk and to mix skim milk and cream in the proper proportions afterwards. Human milk is alkaline and lime-water is used to produce the required condition.

Mother's milk varies with the age of the child as well as with the individual; and in the hospital the nurses make up the food for each infant according to prescription of the six ingredients, of which some are artificial solutions, provided for the purpose. The following is a typical prescription.

	C.c.
Cream (32 per cent. fat)	75
Lactose solution (2 per cent.)	121
Whey	858
Fat-free milk	59
Lime water	60
Sterile water	27
	1,200

The milk mixture is then carefully put into separate bottles, one for each feeding. Many thousands of such combinations are used at the hospital. The milk is kept at 40° F. and the constituents are kept at the same temperature or lower. Just before the milk as modified is given to the infant it is warmed to 100° F., but none of this that is left is kept over for use at a later time.

It might be thought that milk produced with so much care would necessarily be expensive, but Dr. Vincent states that due to economy, among other things by having no cows that do not give a good return for the cost of keep, the expense is not greater than the average for ordinary milk and in fact that the hospital pays only 75 per cent. of the average price of ordinary milk in the metropolis of London. It would seem that in American cities it ought to be possible to procure milk of the grade of certified milk at a less advance beyond the ordinary price than is usually charged.

As old age comes on it appears that milk again becomes a specially valuable diet. In this case buttermilk and other fermented milks are said to be particularly suitable. This subject is, however, not one to be taken up at the end of a paper.

GEOLOGY AND PUBLIC SERVICE[1]

By Dr. GEORGE OTIS SMITH

DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY

THE subject on which I have been asked to speak presupposes a science that is practical—one that serves others than its devotees. It is only utilitarian geology that I shall discuss—that side of the science by some termed economic geology, by others applied geology; but for utilitarian I shall take the definition credited to Tolstoi—solely what can make man better. This human side of scientific work is simply part and parcel of its wider purposes, and to recognize its utility is to ennoble science rather than to degrade it.

Five years ago, in the presidential address of the Geological Society of Washington, Mr. Brooks gave some quantitative expressions of the marked tendency in geology toward practical problems. This growth in the utility of our science during the last quarter of a century was measured by the activities of state geological surveys and of universities, as well as of the Federal Survey. Further, as Mr. Brooks pointed out, the trend that has made applied geology the dominating element in our science has not been limited to the North American continent; it has been world-wide.

The United States Geological Survey was created for public service in the widest sense. Congress intended it to be a large factor in placing "the work of national development and the elements of future prosperity upon the firm and enduring basis of truth and knowledge." To quote further the language used in the debate of thirty-eight years ago, "the institution and continuance of an effective geological survey" was then regarded as a measure such "as will prevent the waste of natural resources, clear the way of progress, and promote the triumphs of civilization." Such a declaration of purpose, though more eloquent, was in full accord with the report of the National Academy of Sciences and surely leaves the federal geologist free to devote his science to public service, without fear of just criticism.

The present status of our science forecasts an even larger usefulness in the future. In oil geology alone the profession has won a place in the business world undreamed of 10 or even 5 years ago. When we see single corporations having in the field more oil geologists than the United States Geological Survey, we realize that our federal service must rest its claim to consideration on something other than size.

[1] Address given before the Geological Society of America, Albany, N. Y., December 27, 1916.

In other lines, too, the science of geology is gaining the recognition that we perhaps feel has too long been withheld. Especially gratifying is the tendency of constructing engineers to consult geologists in matters related to large engineering projects. To the trained geologist, familiar with the many kinds of rocks and their varied habits of assembling together, it has seemed strange indeed that so many engineers have gone ahead on the theory that rock is rock and that nothing can be learned of the third dimension of the earth's crust in advance of actual excavation. Possibly, however, some of this blame may be laid at our own door, for geologists do not always seem firm believers in the practical side of their own science, and only in these later years have we learned to talk of the facts of geology with any approach to the quantitative exactness that engineers expect. Even now a wide difference in degree of scientific accuracy and refinement may be noticed in the manner in which we handle data in our own particular specialty and data relating to some other phase of geology or to another branch of science. This lack of respect for specialized science may sometimes be found in our own midst, even though we call ourselves specialists.

The opportunities for expansion are plainly before us, for the practical worth of geology is now widely acknowledged. How can we best increase the contributions of geology to mankind? Has the science other possibilities? What is its relation to public service?

In the last three years it has been gratifying to see the preparedness issue broaden so as to include the contingencies of peace as well as of war, to hear of industrial as well as of military preparedness. But back of both, and indeed including both, there needs to be a more vital preparedness—the preparation for citizenship. In any day and generation this test can and should be applied to any religion, philosophy, or science: Does it make good citizens? It is therefore with real concern that we ask ourselves this question: Does geology contribute to citizenship?

The president of this society in a thought-inspiring address at the University of Chicago convocation this year, made reference to a little red-brick building here in Albany, which this city does well to preserve—the laboratory of James Hall. And I believe Doctor Clarke is right in regarding that small and plain structure as the source of broad conceptions of the philosophy of evolution, which, radiating outward, have influenced not only our science, but also your state and our country.

The sciences of geology and astronomy are founded upon postulates which they in turn have done much to make real—the permanence and universality of natural laws as we of to-day know them. By training and almost by second nature the geologist may be a conservative in politics; at least, the believer in natural law should possess the patience to wait for results in this particular epoch of this geologic era. By

training the eye to see far back into the earth's remote past, geology can add to our power to put correct values on the events and changes in the brief present in which we happen to live.

There is another way in which geology especially contributes to the training of an enlightened citizen. Some one has said that a man's breadth of mind is measured by the diameter of his horizon. Geology as a study and especially as a profession leads to wide travel, and travel surely maketh the broad man. This advantage may seem to us so much a matter of course that we underestimate its silent influence in fitting us for citizenship. The geologist has the opportunity to think in terms of country rather than of community, of continents rather than of country; and his broader outlook over the world surely gives perspective, just as his longer view back into the past gives poise.

In an address at the University of Illinois I referred to the inspiration and incentive which come from Professor Chamberlin's conclusion that there is good reason for measuring the future habitability of the earth in millions or tens of millions if not hundreds of millions of years. This belief in the high probability of racial longevity is, as you know, the result of an exhaustive analysis of the past as revealed by geology and of the future as forecast by astronomy. But now I wish to add my personal acknowledgment to our greatest American geologist for the inspiration gained from a talk with him several years ago, when I realized that it was this scientific expectation of the evolution of humanity continuing through these millions of years that was prompting him to public service not limited to his own city or country.

The geologist's appreciation of that delicate adjustment of earth to life by means of which "life has been furnished a suitable environment for the uninterrupted pursuit of its ascensive career" and the geologist's vision of the continued adaptation of the earth to the uses of man together constitute a real call to larger service. No one has more reason than the geologist to believe that wise utilization of nature is essential, now that man the engineer has become so effective a geologic agent; nor can the geologist overlook the need of a social organization that will adequately serve the larger and higher demands of humanity, now that man himself controls in large part the adaptation of this earth to man in his further evolution. We believe that the Golden Age is in the future, but it will be of man's own making.

This tribute was paid a year ago to the work of the geologist and engineer by one in high official position who has a vision of things as they are and are to be—Secretary Lane:

> This is a glorious battle in which you are fighting—the geologist who reads the hieroglyphs that nature has written, the miner who is the Columbus of the world underground, the engineer, the chemist, and the inventor who out of curiosity plus courage plus imagination fashion the swords of a triumphing

civilization. Indeed, it is hardly too much to say that the extent of man's domain and his tenure of the earth rest with you.

Keeping in mind these thoughts of the larger things of time and space, I desire to mention what may be termed the professional obligations of geologists. As scientists, working in a practical world on problems that have come to have very practical bearings, we may need to take special care that our scientific ideals be not lowered. As an associate in a large group of geologists I have been proud to see the science of geology win this larger recognition in the market-place, for I hope to see our science cooperate in the further raising of business ideals. There can, however, be no double standard for geologists—one for guidance in research work in pure science, the other for purposes of professional exigency. As geology enters into the larger sphere of usefulness, there naturally come to the geologist opportunities somewhat different from those of the laboratory or lecture room. The profession in its newer activities encounters stresses for which new factors of safety must be figured. As I look at the demands now made upon geologists, the temptation to lower our ideals comes not so much when our task is to find something as when we may be called upon to prove something.

The geologist sent to South America to determine the extent of an ore body or to Oklahoma to discover an oil pool must needs bring into play every resource of a trained mind in order to wrest the truth from secretive nature. This is a contest which calls for geologic science at its best, and in which scientific ideals are in no danger. A demand of another kind, however, is made upon the geologist who is asked to certify to some doctrine in the conservation creed, it may be, or to testify in support of some contestant in a court of law. Professional demands of this type may cause our scientific ideals to tremble, if indeed they do not suffer a tumble. It is for this reason that a geologist's ideals are safer in the field than in the court-room; Mother Nature is a better associate than the goddess who goes blindfold.

Yet the problem faces us and we must answer our own question: What are the professional obligations of the geologist? Possibly the official geologist is less exposed to temptations of this type; he is allowed to make his testimony follow the evidence. At least I remember that the Survey geologist published, uncensored, his estimates of coal reserves, even though his statement did not fit in with the popular argument for conservation; nor was the official opinion required by the statute as to the influence of forests on stream flow given until field examinations by geologists and engineers furnished a basis of fact; nor again do I believe that the federal geologists who testified as to the mineral character of petroleum were in any degree influenced in their opinion by the chance circumstance that this was the government's con-

tention. On another occasion the federal geologist whose duty it was to defend the official classification of land in a western state had definite instructions to reverse the Geological Survey's position in the matter if new evidence should indicate an error of judgment, even though such action would have enabled the railroad claimant to win the land. Nor should a government geologist hesitate to file notice of a correction in some assays earlier introduced as evidence, even though he thereby strengthened the land claimant's contention. Here, of course, the issue was plain; the duty of the public servant was to see that truth prevailed, even though the government might seem to lose its case. In two other of the instances I have mentioned some degree of temporary popular favor and freedom from current newspaper criticism could have been gained by a different course, but I believe that in the end the good name of science would have been besmirched.

Yet in courts of law we now see geologists testifying as experts on both sides of the case, and too often as experts on subjects on which they would not be regarded as specialists by their fellow geologists, or at least on specialized phases of geology which they themselves might hesitate to discuss before this society. But even when such opposing witnesses are both eminently well qualified, what is the spectacle presented to the public? One expert testifies that the thing under discussion is absolutely jet-black; the other that, as he sees it, it is purest white; whereas it may be that without the legal setting the same thing would present to most of us varying shades of gray, or perhaps some one using a higher power of lens might call its general color effect rather spotted. I regret to add that this suppositional illustration is almost paralleled by an important case in which two of my own friends, both honored fellows of this society, were the opposing expert witnesses; and afterward the judge told me that he could believe neither, although he would have taken the unsupported opinion of either one had this geologist been in the pay of the Court! Does not such a statement by an eminent jurist put geologic experts on a par with other expert witnesses, and would it not be a "safety first" measure for geologists to decline professional work of this type until the day comes—and I think it is not far off—when the court will summon the expert witness and compensate him for his services to the state in telling the whole truth and not that special part of the truth which favors one litigant? This society wisely put itself on record last year as recognizing the urgent need of this reform in legal procedure, but to be effective resolutions need to be adopted by each individual geologist.

As first suggested to me, the subject on which I was invited to speak to-day was geology in the national service, but I feared if thus expressed my topic might seem to limit opportunities for service to the nation to those of us who are on the Federal Geological Survey. The president

and more than a score of other fellows of this society are in the public service as officials of the several states; and too much credit can not be given to the long succession of state geologists who for nearly a century have both contributed to the science of geology and guided the development of their states. A few years ago Doctor White, in addressing the West Virginia board of trade as its president, referred to the function of the state geologist as that of "a kind of mentor or guardian of the state's natural economic resources."

Yet I would not limit the obligation for public service to those of us who happen to be public servants. The use of the United States Geological Survey as a training school for professional geologists in private practice can not be regarded as wholly a hindrance to the nation's business when viewed in a large way. The spirit of public service can be carried over into the work outside the official organization, and I like to believe that there is a persistence of this same purpose on the part of our Survey graduates that will lead them to do their share in planning for the utilization of the nation's mineral wealth, not merely so as to increase dividends for the corporations that employ them or to assist a few capitalists in speculative endeavors to corner some limited resource, but also so as to benefit society in a large way through future decades. Why can we not be trained scientists and professional geologists and loyal citizens at one and the same time?

President Vincent has referred to the sweeping indictment of professional schools, with all their modern efficiency, as turning out graduates "bent upon personal success and regarding the public as a mine to be worked rather than a community to be served." In whatever degree unwarranted, this criticism, as President Vincent points out, is in itself encouraging as a sign of general discontent with self-centered careers. And there is another approach to this subject of the civic obligations resting upon us as geologists. Those of us who have shared in the benefits of the American educational system, up to and including the university, must realize to what a large extent our education has been gratuitous. As Doctor Becker once expressed it to me: "Men who seek or use their university training solely for their personal advantage are almstakers. Only by public service can educated men repay the debt they incur and thus fulfil the designs of the founders."

It is a fortunate sign of the times that applied science is touching more and more upon the human and social side of its work. Measure of the breadth of view already attained in this public service idea is found in this month's issue of a leading technical journal, *Metallurgical and Chemical Engineering,* wherein the longest editorial bears the title "Expensive Slums." Social responsibility is acknowledged and civic duty set forth in the closing sentence of this editorial:

> **It is needful for industries that they be in good standing, and they can not maintain good standing so long as they have slum attachments.**

So too it is eminently fitting that in a technical volume bearing the title "Iron Ores" the closing chapters should discuss the large social questions of public and private policy. The author, a geologist and fellow of this society, properly regards the social value of iron just as worthy of his thought as the purity of its ores. Indeed, it is simply the need of society that makes the mineral hematite an ore and thus the object of the geologist's special study.

In my administrative report for the past year I had occasion to refer to a professional paper by Doctor Gilbert now in press. In his wonderfully broad and complete investigation of the mining-débris problem in the Sierra Nevada the geologist began with the antagonism of mining and agriculture, but he soon found that his research also involved questions of relative values between commerce and irrigation and power development. So this report, thoroughly scientific in data and method, will illustrate how high a public service can be directly rendered by the geologist. Nor is this a new departure: some of us belong to the generation to whom Monograph 1 of the United States Geological Survey was a source of inspiration in our student days. That monumental work by the same author, a classic in its exposition of geologic processes, was the result of an investigation also planned as the answer to an economic question of large civic importance. Director King thus stated in 1880 the purpose of the Lake Bonneville monograph:

> Is the desert growing still drier or is it gaining in moisture are questions upon the lips of every intelligent settler in that region.

Moreover, aside from making our science more human, there is the larger need of humanizing ourselves. Doctor Favill, of Chicago, in addressing a group of business men last winter, gave them this professional advice: "Have an outside interest;" and the outside interest he prescribed was political or social activity. This physician regarded it as conducive to individual happiness as well as helpful to society that "every honest, able-bodied, red-blooded, clear-thinking man should have his mind set on what is the right thing for him, for his community and his country to do."

The Austrian geologist Suess may furnish the best illustration of the happy combination of scientist and citizen. He was a leader not only in the science of the world but in the parliament of his country. A close student of geologic discovery even after reaching fourscore years, Professor Suess was equally keen to learn of political progress the world over, and in a letter to me within a year of his death he inquired particularly about the reforms in public-land administration in the United States.

Appreciation of civic duties has fortunately not been lacking in

American geologists: one of the best volumes on citizenship was written years ago by Professor Shaler, and it is worthy of mention that in that book he emphasized not so much the opportunities for service in high station, for he states that the best work in the practise of citizenship is done in the town or precinct.

> In these fields of activity the spirit of the freeman is made; if the local life be not of a high citizenly character, all the constitutions in the world will not give the people true freedom.

And it has been said of Professor Shaler that he not only preached good citizenship, but, what was better, he never neglected his own political duty. While we must properly look upon enlightened citizenship as a 365-day-a-year undertaking, there is one day in each year, or two years, or four years when a special duty is laid upon each citizen of the state and nation, and in these times no one is better qualified to exercise the right of suffrage than the geologist. A few weeks ago, too, we learned that even in this great country of ours, where eighteen million ballots were cast at a single election, individual votes have not lost their power to influence the result. And how true it is that education of the scientific type is essential to a correct understanding of many of the issues of the day.

In a leading editorial, the day before election, a nonpartisan writer mentioned the discussion of prosperity as a campaign issue and remarked that

> Analysis of the interminable political arguments about it would probably disclose that in the main they consist of about 95 per cent. imagination and exaggeration, in equal proportions, 5 per cent. of fact, and of unbiased opinion not a trace.

A low-grade ore of that composition surely needs a citizen who is a scientist or engineer to make the necessary separation and concentration.

Take another political and economic issue that must be faced—the length of the working day. Professor Lee, of Columbia, recently emphasized the fact that the determination of the proper number of hours of work is primarily a problem of physiology, although too often economic and social considerations have been made paramount. Must we not agree with the physiologist, at least to the extent of admitting that it is all too evident that here is a present-day issue of large importance which deserves scientific rather than political treatment? Or we may say, here is a civic question that demands the attention of citizens who have had scientific training. Who can better weigh the opposing elements of this question—on the one side the cumulative fatigue of the individual producer and on the other the economic requirements of society as the consumer?

To mention just one other of the larger issues of the moment, the

railroad question is one so intimately tied up with the geographic relations of mineral resources that the geologist citizen is eminently well qualified to consider how dependent is industrial opportunity upon fair freight rates. When we realize that the railroad earnings from the transportation of the raw products of the mine alone exceed the earnings from passengers and also exceed the freight receipts on all products of both farm and forest, we have a measure of the interdependence of the mineral industry and the railroads. The proper regulation of common carriers thus becomes a prerequisite of the full utilization of our mineral resources, and on such a political issue no citizen should have a larger interest or a more intelligent opinion than the geologist. It is therefore more than a happy coincidence that President Van Hise has rendered large service to society in his contributions to the railroad and labor problems; the broad training of the geologist is being utilized in the work of the publicist.

Have I not already shown that the geologist is well qualified by his special training to serve his day and generation, not only in the capacity of professional adviser but, better than that, in the rôle of fellow-citizen? It may be rather late in this discourse for me to select a text, but there is an old saying in the book of Proverbs that has been much in my mind for several months—"Where there is no vision the people perish." Imagination is necessary in our science, and it is equally essential to the larger citizenship. I believe the geologist possesses the vision; his duty and privilege is to let that vision guide him to a larger public service.

ADVENTURES OF A WATERMOL

A ROMANCE OF THE AIR, THE EARTH AND THE SEA. II

BY PROFESSOR H. L. FAIRCHILD

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SYNOPSIS OF THE PRECEDING CHAPTERS: In the January number of the MONTHLY the water molecule tells of its birth, in an ancient volcano perhaps one hundred million years ago, and relates some of its romantic experiences, in the atmosphere, cloud, ocean, glacier and iceberg.

IN THE OCEAN ABYSS

THE water in which I was liberated from the iceberg was fearfully cold and heavy and the polar current carried me slowly down to great depth in the abyss of the ocean. It was terribly cold and the pressure was immense, even more than in the glacier. I went down to near the bottom of the deep ocean, down 20,000 feet, I should think. Though the temperature was below that for freezing at the surface, the pressure and the salt substances which we watermols held in solution prevented our turning into ice.

To this great depth the sunlight never reached. At lesser depths there was a faint light or phosphorescence produced by curious fish and other animals. It was a weary, weary time; perhaps not worse than in the glacier, but different. In the glacier, as I have said, it was a sort of frozen silence. Here it was a liquid solidity. In the glacier we watermols were kept in stillness and idleness, while here in the ocean deeps we yet had cold and darkness and crushing pressure and besides we had to keep in captive subjection the many substances which are found in sea water.

Very slowly the cold water in which I lay drifted toward the equator. But it took long ages of time before we reached the equatorial region. In the warm tropics the watermols at the surface of the sea are stolen away so rapidly by the air that the deeper water very slowly rises to fill the space. Slowly, dreadfully slowly, I was lifted upward. Maybe it was a million years until once more I was at the warm surface of the ocean.

IN TROPIC SEAS

Floating about in the warm water of the tropic sea, in the bright sunshine and with many curious animals swimming about, was much nicer than being in the frozen heart of a glacier or in the silent pres-

sure of ocean abyss. And curious adventures befell me here. Once a frond of seaweed seized me and built me into its pulpy mass, and as a part of the plant I was floated about the sea during all the life of the fucoid, which must have been more than a century. Once a big sea-jelly, or so-called jellyfish, gulped me down into his baglike stomach and sent me in the current through his many tubes or canals, and then he added me to his soft, watery flesh. But one day the angry waves in a big storm dashed my seajelly on the rocks and he was beaten to death, and in the decay of his substance I was liberated. Many of the different kinds of animals which live in the sea have, at one time or another, made food of me and have carried me into their flesh or the cavities of their bodies. I may mention the coral polyp, the sea urchin, the oyster and the devilfish. But the animals all die, while I live on. My adventures with some of the larger and higher animals will be told later.

When free in the ocean my fellow watermols and I were always busy, holding in captivity or solution the molecules of many gases and solids. In later times, more than once I have been in the water current that was sucked through the gills of a fish or other animal when molecules of oxygen were taken away and carbon-dioxide molecules given back in exchange.

I have been in all the great currents of the ocean, such as the Gulf Stream, and have felt the daily tides for many millions of years. I have been in the spray on the crest of storm waves, and in the white foam of breakers on the shores of coral islands.

During this episode of which I am telling, the tides and currents of the tropic seas drifted me about for a long time, until one hot day when I was lazily resting at the very surface of the water I was grasped and pulled away from my fellow watermols by the warm air, and again was floated far away in the atmosphere, a captive of the nitrogen molecules.

In a Subterranean River

Sometime, it was certain, I should be again dropped on the sea or land. And again I was built into a raindrop. After helping to carry the electricity of a terrible lightning storm I fell on the ground in some faraway land. The ground absorbed the water and I went down and down into the earth. Finally I fell in a little stream which came out as a spring on a sunny hillside. Flowing down the slope and then a long way down the valley the little stream joined a small river. Many miles further the river passed beneath the surface of the ground and plunged into a subterranean channel in limestone rock. Finally it carried me into a lake in a great cave in the limestone. For years I was there in darkness. This was a new experience.

Like the depth of the glacier, and the ocean, it was perfectly dark. But it did not have the great pressure and the extreme cold. And there were no waves and no strong currents because there were no winds. It was a tiresome place. I only had to help hold some calcium carbonate in solution.

All the underground river channel and the cave had been the work of other watermols, my predecessors, for thousands of years. But not only had they dissolved and removed the rock to make the cave, but to show that they could build as well as tear down they had formed beautiful objects in the cave as samples of their construction. Long masses of translucent limestone, of white, yellow and pink color, and shaped like icicles, were left hanging from the roof of the cave-stalactites. In some parts of the cave, which the lake did not cover, conical, needle-shaped and columnar masses of the same elegant material rose from the floor-stalagmites. The beautiful material called "Mexican Onyx" is of similar origin. Some other examples of our constructional work are the lime deposits made by hot water in the open air, as at Mammoth Hot Springs.

Very slowly the drift carried me through the lake and finally out of the subterranean channel into the open air and light.

In a Coal Plant

The river in which I floated out of the ancient cave carried me into some lake, and after a time I was again taken up by the air. And again I was in a raindrop and fell upon the ground, and sank into the earth. I wondered what new experience was coming; and the event was unexpected. Some of my fellows were drawn back into the air, which was always seeking to keep us. But I sank deeper in the earth. I was drawn along between the mineral grains which composed the soil, by the attraction called tension or capillary attraction. Then I lay close against the tiny rootlet of a tree. The rootlet took violent hold of me and drew me right through its wall and into its interior. In a watery fluid I was then carried into a larger root; then into the trunk of the tree: then up the tubes or ducts of the wood; out into a branch; into a branchlet, and at last into a leaf. All this time I was compelled, with multitudes of other watermols, to carry along other substances which the tree required for food. These were mineral compounds containing nitrogen, phosphorus, sulphur, potassium, etc. We watermols were the food-bearers for the tree. Our ride in the sap of the tree was not free; we had to work our passage.

In the leaf we assisted the tree in preparing and digesting its food. I was helping in the life and growth of one of the strange trees of the Coal Period, called Lepidodendron. And actually I was helping to

Courtesy of Eastman Kodak Co.

FIG. 12. WATERMOLS ATTACKING THE CONTINENT.

produce coal, in China. By the green substance in the leaf, known as chlorophyll, the tree was able to draw a supply of power from the sun. Carbon-dioxide was taken in from the air and broken up. The carbon was kept to unite with us watermols and the oxygen was given back

FIG. 13. WATERMOL ARCHITECTURE.

FIG. 14. WATERMOLS TEARING DOWN THE MOUNTAINS.

to the air. The substance of the tree was built up from us watermols and the carbon of the air. Many of my fellows were used as food for the tree and were built into its wood. I have been told that this par-

E. H. Barbour, photo.

FIG. 15. WHERE WATERMOLS UNDO THEIR OWN WORK.

ticular tree in its old age fell into the marsh in which it grew, and became part of the peat deposit which is now a coal bed one thousand feet in the earth. Some of the watermols which worked with me in the sap and leaf were built into the wood of that tree and are now down in that ancient coal deposit. More than once have I just escaped such fate. But after being employed in various kinds of chemical work, and in carrying sugar to the tissues of the tree, I was fortunate in escaping. One bright day when I was near the surface of the leaf I passed out, by evaporation or transpiration, into the freedom of the air and sunlight.

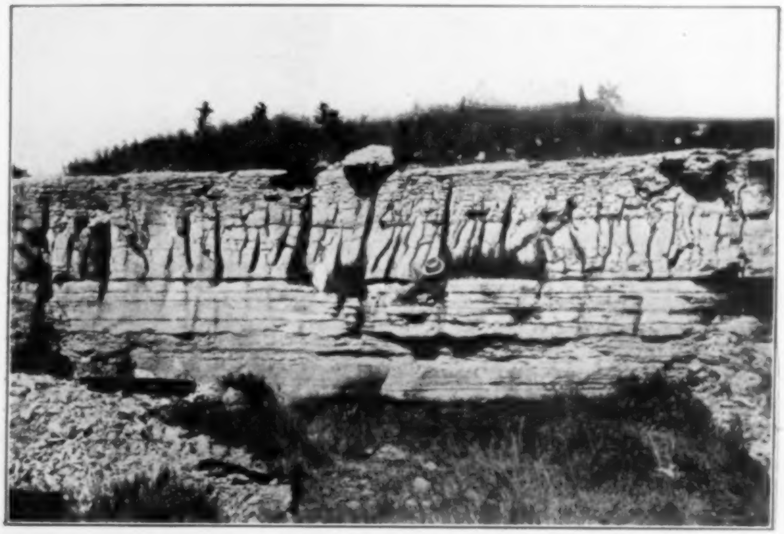


Fig. 16. Limestone Beds Deposited by Watermols.

Almost a Planet

Again I was up in the sky, with more freedom of vibration, the happiest of all the many conditions I have found. I knew that sooner or later I would be carried down to earth again by snow or rain. But this time I was driven by collisions with other molecules on and up and up until I was far from earth and out in the very rare atmosphere. Here all the molecules, nitrogen, oxygen, hydrogen, and we water molecules, were farther apart, with less interference, fewer collisions and longer free paths of vibration. The elastic rebound from some collisions gave certain molecules, especially hydrogen, such velocity in outward paths (critical or parabolic velocity) that they passed beyond the earth's control, the earth's effective gravitational pull, and were lost to the earth; though not lost to the solar system. At times a lucky (or unlucky) rebound might have thrown me so far away that the earth-pull could not entirely check my flight and draw me back. Then

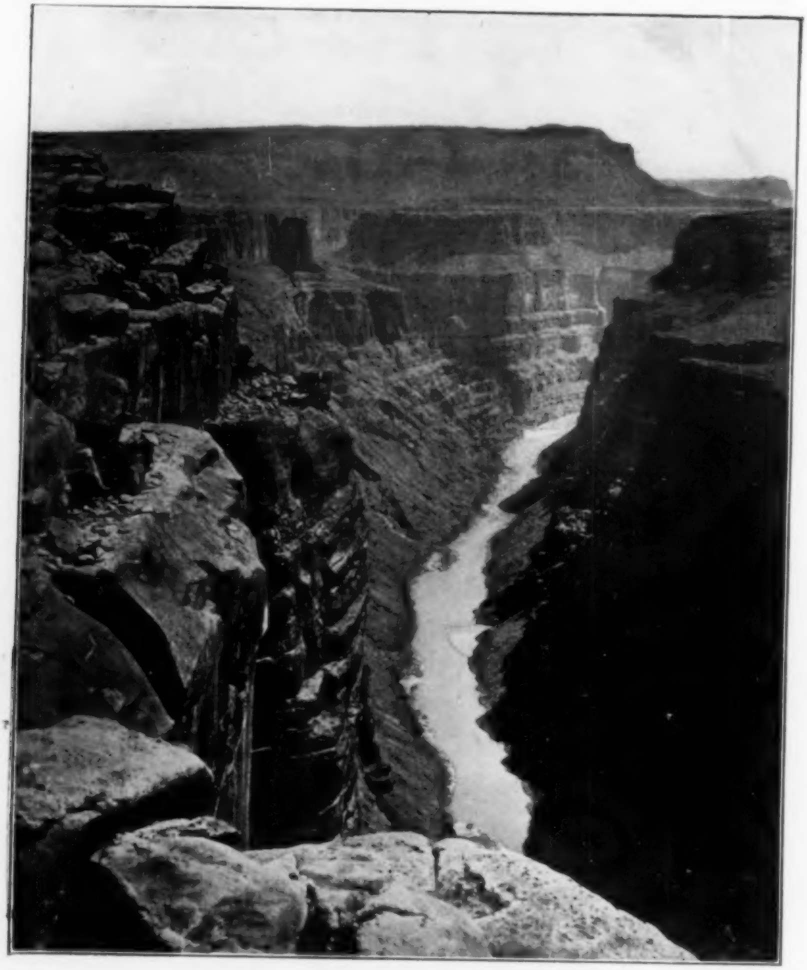


Fig. 17. A Little Bit of Watermol Work.

I would have been a really free molecule in interplanetary space and would have had my own independent orbit around the sun. Ah! then I would have been a planet of the solar system, a single molecule, a little brother of the earth and Jupiter. Perhaps it were more correct to say, a little child of the earth and nephew to Jupiter. Multitudes of watermols and molecules of lighter gases, as hydrogen and helium, have left the earth and are either moving in space about the sun or have been captured by the planets or the asteroids. As the sun's effective attraction reaches far beyond the orbit of the most distant planet probably few molecules could ever escape into stellar space. It is believed that the present ocean and hydrosphere does not represent all the water

which the earth has exuded or perspired, especially in its early or youthful stages, when it was smaller and its attractive power was less. But to counterbalance this loss it is probable that the globe has acquired many watermols and other molecules which had been wanderers in space, having been expelled from the sun, or perhaps were lost children of the other planets or emigrants from the moon.

That would have been a far leap for me, into the deep abyss of space. I was too timid, and clung to the atmosphere. When I bounded into space I took an elliptical instead of parabolic curve and so returned. I resisted the temptation of becoming a tiny planet all by myself: a little rival of the planets and asteroids. But, after all, it would not have been a very vainglorious existence, because no astronomer would ever have discovered me. I should have remained unknown,

FIG. 18. WATERMOLS REMOVING THE LAND.

a lost watermol wandering in the infinite spaces, unmissed and useless. And yet! according to the law of gravitation the great sun and even the distant star-suns should have felt the pull of my attraction. But such a tiny pull!

However, some day, if I survive long enough all the dangers that face a watermol and have grown tired of the earth, I may venture the leap to outer space and abandon this old sphere and let it take of itself without my help.

IN THE SOUTHERN HEMISPHERE

So I remained in the captivity of the air, and the swift currents of the outer atmosphere carried me downward and far southward, and I found that I was in the southern hemisphere.

It would be tedious to relate many of my adventures there, as it would repeat some already told. The time was early Mesozoic, or the Period of Reptiles, and I met some of the queer plants and queerer animals of the ancient reptilian time. The lakes and rivers and clouds and storms, and halos, coronas and rainbows that I helped to form were not unlike those of all lands in any time. But the life of different lands during the several geologic periods was very changeable, and this gave variety to my existence.

I was long immersed in the waters of the South Pacific ocean, which at that time was not so large as to-day, because the dry land in the southern hemisphere was more extensive and the southern con-

Eastman Kodak Co.

FIG. 19. WATERMOLS AS ICE DECORATION.

tinents were then connected. I fell in with some of the huge swimming reptiles. One was fish-like in shape, with paddles, and perhaps thirty feet long. He had an enormous mouth for seizing fish and a multitude of sharp conical teeth. This was the Ichthyosaurus, but I doubt if he knew his name. Another one, the Plesiosaurus, had a snake-like neck and head on a short body. Among the big mollusks were the Ammonites, related to the modern pearly nautilus. Once on the land I saw some of the huge Amphibians of that and the preceding period. One was like an enormous frog, but had powerful teeth and bony armor, and was near ten feet long. How he could jump! The

FIG. 20. WATERMOLS ESCAPING FROM A GLACIER.

curious Cycad trees had some assistance from me in their life and growth.

For one or two hundred thousand years I was imprisoned in an Antarctic glacier. Once I fell in a storm on the east slope of the Andes mountains, and was swept down into the headwaters of the Amazon river, and helped to make that big river all the way to the sea. That landed, or oceaned, me under the Equator. There the warm and still air held me for a long time in the Zone of Calms. I just had to lie

around in the Doldrums, sometimes in the surface waters of the warm sea, and sometimes in the air. I do not remember just how I got out of the Doldrums.

Destroying the Continents

Let me interrupt the story to say that we watermols are chiefly responsible for changes in the land surfaces of the globe, and incidentally for making most of the fine scenery. Of course many of the best scenic features are credited to the Devil, but we are the real little devils that tear down the land. We do not like to see dry land standing up in the air. We think it should all be in our possession, nicely spread out on the bottom of the sea.

So we are always busily and persistently at work cutting away the continents and islands and carrying the detritus to the sea. Eventually everything on the surface of the land finds its way into the ocean, and we are the transporting agency.

If the continents will only stand still a little time we will get them. We would have destroyed them long ago but for the interference with our work by the interior forces of the earth—heat and gravitation. They deepen the ocean basin and crumple and raise the lands so that we have to do much of our work over again. At different times we have had most of the continental surfaces below our level and in our possession, but those terrible powers have lifted the sea bottoms into the air and we watermols have to pull them down over and over. But we are patient and tireless and keep right on at our task. When you stand at the ocean shore you see us always restless and sometimes fiercely tearing the shore. We have been doing this destructive work on the lands and constructive in the sea ever since the infant globe acquired an ocean, when it was somewhat larger than the moon, and we shall keep tirelessly at it as long as any land exists to challenge us.

We have many ways of attacking the land. As bees and ants have division of labor, so we watermols have our varied work; but we can change, and any of us can do any kind of watermol duty. Sometimes we simply dissolve the rock, such as limestone, salt or gypsum. As we made those rocks it is quite easy for us to reclaim them. Sometimes we merely dissolve the cementing material and cause the rock to fall to pieces. Then we wash the loose stuff down the slopes until our fellows of the creeks and rivers can grasp it. Our rivers make the canyons and the valleys. We are the valley-makers. Cascades and cataracts mark the spots where we find a little hindrance or delay in carving the valley. They do not last long. And the lakes are short lived, for the watermols there are too inactive; so we either drain the lakes by deepening the outlets or fill the basins with detritus.

When the air temperature is too low for us to exist and work as

S. Calvin, photo.

FIG. 21. TRACK OF A GLACIER.

fluid water we do not wait for a warmer spell, but get busy as frost and snow and ice. In high mountains and polar regions this is our favorite manner of working. The mountains do not last long. Nothing can stop our work of destruction or even discourage us. Here and there we may be hindered a trifle, but the mountains of to-day are big only because they are new, and in time they will be carried to the sea as we carried those of ancient time.

When we get the rock stuff fully in our possession we spread it out in beds—the fine stuff, like clay, in delicate horizontal layers and the coarser, as sand, in thicker sheets. In this way we have made the geologic record for many millions of years. In graceful wave lines and elegant ripples we have written our play time along the ancient shores; while in the even-bedded strata of clay or sand or lime, filled with the remains of the ancient animal and plant life of the sea, we have inscribed the wonderful record of the deeper or more quiet waters.

FIG. 22. WHERE THE WATERMOLS DANCED.

I have helped to make some of

your famous scenic features, like Yosemite and the Colorado canyon, and have helped a little in pulling down the Alps and Sierras. I have been in many big and little waterfalls and lakes and streams innumerable. The next time that you stand before Niagara or by the Mer de Glace, or admire the quiet stream or the frostwork, look out for me. If I am not there it is because I have another job.

We watermols will all be working after you humans are gone from the earth, just as we were a hundred million years before you came. Perhaps if you would go back to breathing by gills so that you could live again in the sea you might survive longer. The ocean is the great reservoir of life, which may there persist after we have conquered the continents.

Why do we work so tirelessly? And do we work for the love of it? Well! motion, energy, activity is our nature; and we are restless for the same reason that the bird sings or the bee labors. Do you humans rush about like mad and strive and rob and kill each other just for fun, or because you can not help it?

(*To be continued*)

THE PROGRESS OF SCIENCE

THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION AND THE ORGANIZATION OF SCIENCE

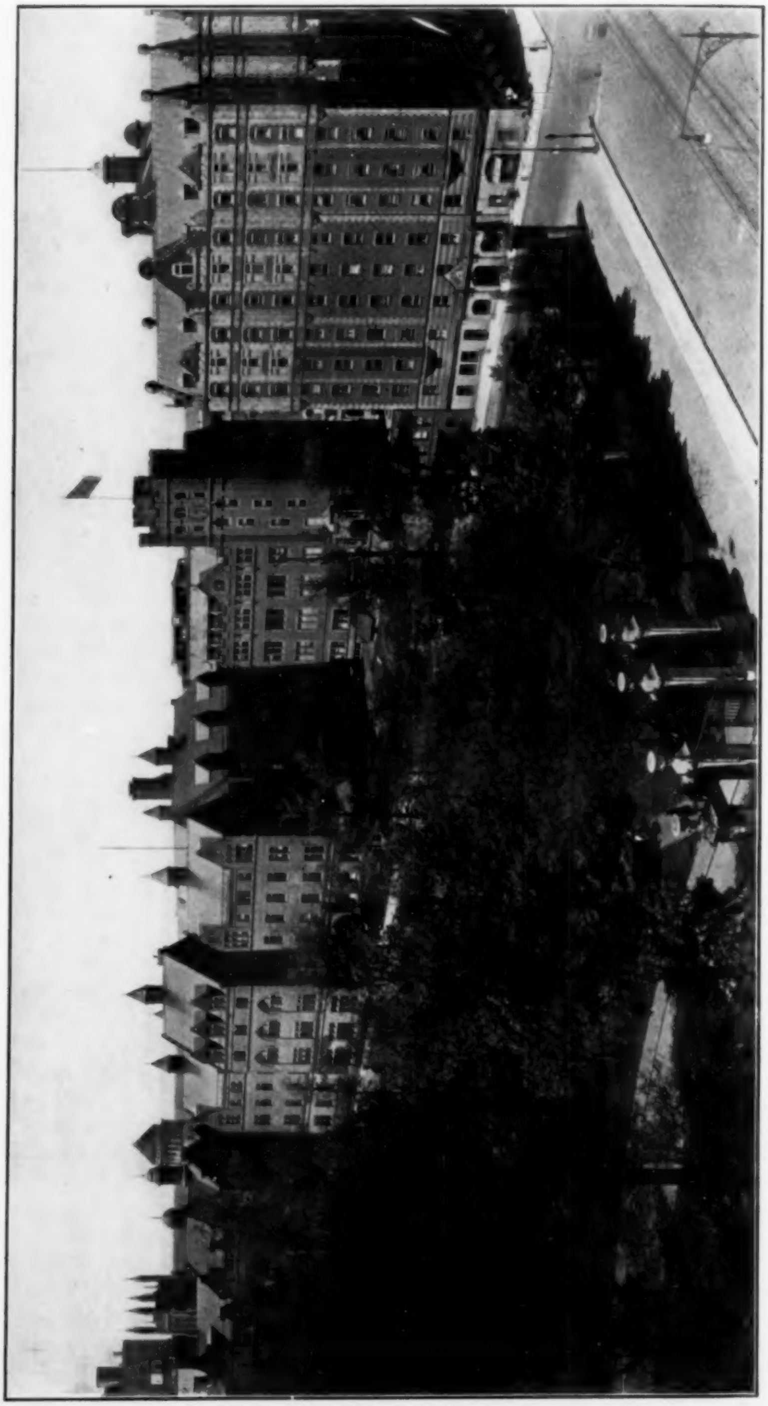
THE forecast of the meeting of the American Association and the national scientific societies affiliated with it, printed just before the meeting in the last issue of this journal, was fulfilled in all respects. As had been anticipated, it was a meeting of unprecedented size, not only in this country, but, as far as we are aware, in any other country. The attendance can only be very roughly guessed, for while the association gives an opportunity for members to register, not nearly all of them do so, as the only practical advantage is the obtaining of a program. Some of the affiliated societies keep a register of members in attendance, but these have never been brought together for the whole meeting.

The magnitude of the meeting can be best realized from the number of separate organizations in session. Apart from the general session of the American Association and its twelve sections, there were fifty-two national scientific societies meeting during the week, and this number does not include the four national engineering societies and three associations devoted to highway engineering, which held meetings in connection with the section of engineering of the association, the metric conference, the meeting of the Committee of One Hundred on Scientific Research and various other organizations.

Altogether about seventy-five different organizations met during the week and, while there was a considerable amount of overlapping membership, the sessions appeared to be in all cases well attended. In spite of the large number of simultaneous meetings, there was no overcrowding. Six or eight thousand people naturally made small impression on the hotels of the city, which in that week are less crowded than in the preceding and following weeks. Columbia University has in attendance some 10,000 students every day and only part of the meetings were held there. Teachers College, part of the buildings of which are shown in the accompanying illustration, has, counting the students in the Horace Mann School, some 4,000 students in attendance.

The present situation in Europe has attracted universal attention to two factors—the importance of science and the necessity of effective organization—and these are combined in the American Association for the Advancement of Science, which represents the science of the nation, and a tolerably efficient organization of its twelve thousand members for the accomplishment of their objects. The advance in science and organization since the American Association was established in 1848 is truly remarkable. It covers a period from the time when American contributions to science were comparatively few to the present meeting from which we can probably date the time at which America has assumed leadership in scientific research.

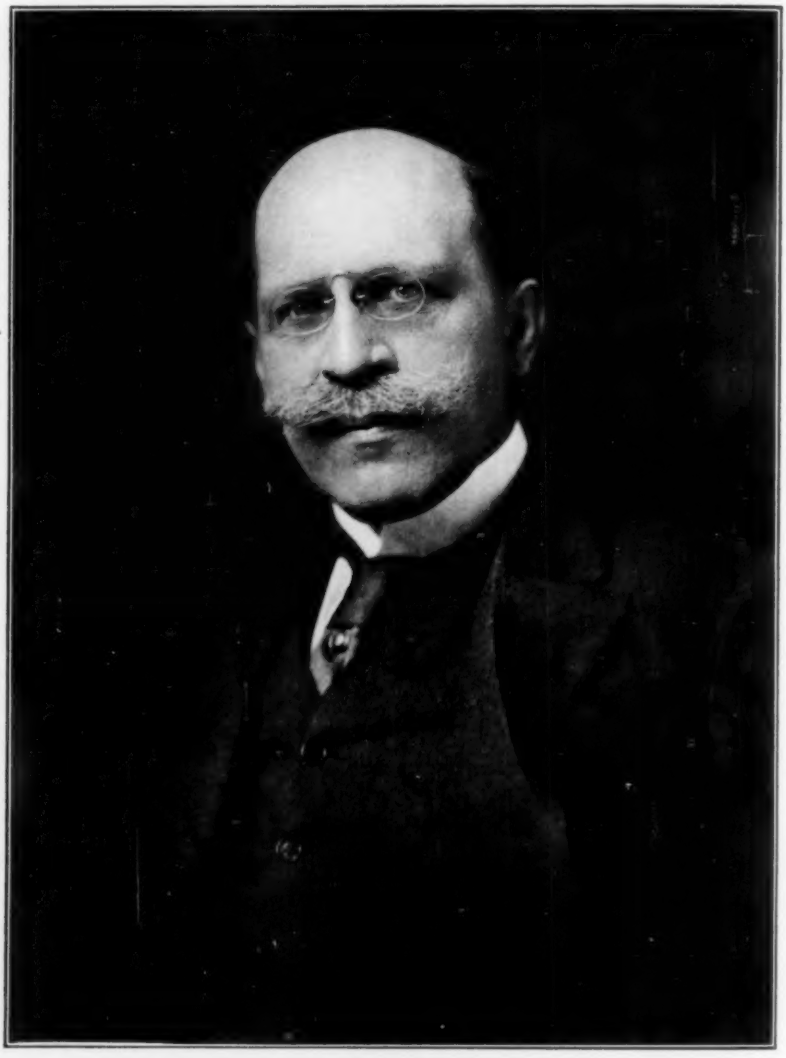
Local societies concerned with the whole field of knowledge had been established in the seventeenth century, the Philosophical Society of Philadelphia following the Royal Society of London, and the Academy of Arts and Sciences of Boston following the Paris Academy of Sciences. The National Academy of Sciences was organized in 1863, with a membership then limited to fifty. Until the establishment of the American Chemical Society in 1876,



THE BUILDING OF THE TEACHERS COLLEGE WITH THE CAMPUS OF COLUMBIA UNIVERSITY IN THE FOREGROUND.

ON THE COLUMBIA UNIVERSITY CAMPUS.

there were no special societies and the loosely organized American Association and the other societies mentioned were the only means of bringing together men in all the sciences then so little specialized that this was possible. In 1875, a formal division of the American Association was made into two sections, one for the exact and one for the natural sciences, and in 1882 nine sections were established. Parallel with the organization of scientific societies scientific journals were established, *The American Naturalist* in 1867, *The Popular Science Monthly* in 1872 and *Science* in 1883. The establishment of these general journals was followed by the establishment of special journals: the *Botanical Gazette* in 1876; the *American Journal of Mathematics* in 1878; the *American Chemical Journal*, the *American Journal of Morphology* and the *American Journal of Psychology* in 1877; the *American Geologist*, the *National Geographic Magazine* and the *American Anthropologist* in 1888, and so on, in increasing numbers to the present time. The Geological Society



HUGO MÜNSTERBERG.

The distinguished German Psychologist and Publicist, professor at Harvard University from 1892 until his sudden death on December 16.

of America and the present American Mathematical Society were organized in 1888, and in the intervening period have been established the large number of scientific societies which met together in New York during convocation week, and represented so impressively the development and differentiation of science in America.

DR. CAMPBELL'S PRESIDENTIAL ADDRESS ON THE NEBULÆ BEFORE THE AMERICAN ASSOCIATION

THERE were printed on the official program of the association the titles of some fourteen hundred papers to be given at the meeting. Among this large number the address of the president of the association, Dr. W. W. Campbell, director of the Lick Observatory, may be selected for notice, not only owing to its official character, but also for its intrinsic interest. The discoveries of astronomy make a strong appeal to the imagination, and it is noteworthy that this least practical of all the sciences is the one which in America has been cultivated beyond all the others, so that the work of the great American observatories is not paralleled elsewhere.

Readers of this journal are familiar with Dr. Campbell's work on the evolution of stars and on comets through the admirable papers we have had the privilege of printing in recent numbers. His presidential address was on the nebulæ, to which Sir William Herschel, towards the end of the eighteenth century, gave the first serious study. In 1845, it was determined by Lord Ross's reflecting telescope that some nebulæ are of spiral structure, evidence that they are in rapid rotation. In 1864, William Huggins discovered that the spectra of certain nebulæ prove that they are masses of gases, shining by their own light. The fourth event recorded by Dr. Campbell was the discovery by Keeler, beginning in 1898 at the Lick Observatory, that the great majority of nebulæ are spirals and that the Crossly reflecting telescope that he used could discover at least one hundred thousand nebulæ in the sky.

Dr. Campbell explained—his clear exposition was throughout accompanied by striking and beautiful photographs—that of about fifteen thousand recorded nebulæ not over three hundred, that is, not more than one fiftieth, are in the one quarter of the sky which contains the Milky Way, and these include nearly all the planetary and large gaseous nebulæ. The other three quarters of the sky contains nearly fifteen thousand nebulæ, not counting the scores of thousands as yet unrecorded. Thousands of spiral nebulæ are known to exist, but not a single one has been found within the Milky Way.

Our stellar system is believed to occupy a limited volume of space, somewhat the shape of a very flat pocket watch, and we see the Milky Way as a bright band encircling the sky, because looking toward it we are looking out through the greatest depth of stars. There is reason to suspect that there is an immense amount of obstructing material in our system, that would be most effective in its long dimensions. If such obstructions are operating upon the light of extremely faint and distant nebulæ, they should produce something like the distribution that is observed among the visible spiral nebulæ.

The probable mass of certain spirals is stupendous, some of them appearing to contain enough material to make thousands, and possibly millions, of stars comparable in mass with our sun. The spectra of some spirals have the characteristics that we should expect to find if they consisted chiefly of multitudes of stars. If we carried our spectrograph so far out into space that loking back our stellar system would be reduced to the aparent size of the spiral nebulæ, we should expect to see a spectrum similar to that yielded by the spirals. Dr. Campbell thus favors the hypothesis that the spiral nebulæ are enormously distant bodies, independent stellar systems in different degrees of development, independent of our own stellar system.

Dr. Campbell concluded his address with the remark: "Working at peace and under extreme encouragement, the astronomers are learning the place of our star and its planets among other stars. If the spiral nebulæ prove to be separate and independent systems, we shall bequeath to our successors the mighty problem of finding the place of our own great stellar system amongst the host of stellar systems which stretch throughout endless space."

SCIENTIFIC ITEMS

We record with regret the death of T. H. Bean, chief of the division of fish culture of the conservation commission of New York; of Clement Reid, F.R.S., late of the British Geological Survey; of A. M. Worthington, F.R.S., formerly professor of physics at the Royal Naval College, Greenwich, and of W. Ellis, F.R.S., formerly superintendent of the magnetical and meteorological department of the Greenwich Observatory.

At the recent New York meeting of the American Association for the Advancement of Science Dr. Theodore W. Richards, director of the Wolcott Gibbs Memorial Laboratory, Harvard University, was elected to preside at the meeting to be held next year at Pittsburgh and to give the address the following year in Boston.

Other presidents of scientific societies elected at the recent meetings are Professor George H. Shull, professor of botany in Princeton University, of the American Society of Naturalists; Professor Frederic S. Lee, of Columbia University, of the American Physiological Society; Professor Robert M. Yerkes, of Harvard University, of the American Psychological Association, and Professor Frank D. Adams, of McGill University, of the Geological Society of America.

Professor M. I. Pupin, of Columbia University, has been elected president of the New York Academy of Sciences, which in 1917 will celebrate its hundredth anniversary.—The Bruce gold medal of the Astronomical Society of the Pacific for the year 1917 has been awarded to Professor E. E. Barnard, of the Yerkes Observatory, for his distinguished services to astronomy.—Governor Whitman, of New York, has granted Dr. Hermann M. Biggs, state health commissioner, leave of absence to go to France, at the request of the Rockefeller Foundation, to conduct an organized campaign to combat the spread of tuberculosis among noncombatants.—Mr. Theodore Roosevelt made the principal address at the opening of the New York State Museum at Albany on the evening of December 29, his subject being "Productive Scientific Scholarship." The address was printed in the issue of *Science* for January 5. Among those who made addresses at the afternoon exercises were Dr. John H. Finley, president of the University of the State of New York; Dr. Charles D. Walcott, secretary of the Smithsonian Institution, and Dr. John M. Clarke, director of the State Museum.

The Naples Table Association for Promoting Laboratory Research by Women announces the offer of the Ellen Richards Research Prize of $1,000 for the best thesis written by a woman embodying new observations and new conclusions based on independent laboratory research in biology (including psychology), chemistry or physics. Theses offered in competition must be in the hands of the chairman of the committee on the prize before February 25, 1917. Application blanks may be obtained from the secretary, Mrs. Ada Wing Mead, 283 Wayland Avenue, Providence, R. I. The Sarah Berliner Research Fellowship for Women of the value of $1,000 is offered annually, available for study and research in physics, chemistry or biology. Applicants must already hold the degree of doctor of philosophy or be similarly equipped for the work of further research. Applications must be received by the first of February of each year. Further information may be obtained from the chairman of the committee, Mrs. Christine Ladd-Franklin, 527 Cathedral Parkway, New York.